A Contribution
to our knowledge of
Hibernation,
and a description of the Minute Anatomy
of some of the more important organs in
the Hedgehog; with the changes that oc-
cur in them during Winter Sleep.

Thesis
for the degree of M.D.
by
Edmond William Wace Carlier. Bès-S
Université de France 1882, and M.B. C.M. Edin-
burgh University 1886. Senior assistant
to the Professor of Physiology in the
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Edinburgh 1891.
MEMORANDUM.

From the

Dean of the Faculty of Medicine.

Prize Theses.

Have the goodness to circulate the accompanying Theses in the following order:—

Professor Sir L. F. Stewart

Lehene

Simpson

June 1891. Affixed by S. Dean.

[Signature]
Gentlemen.

The present work on hibernation which I have the honour of submitting to you, as my thesis for the degree of M.D. in the University of Edinburgh, contains the result of numerous personal observations, made with great care and without undue haste.

The only animal available was the hedgehog, and what I have stated may not necessarily apply to other species of hibernating animals.

After a careful and prolonged study of all the literature which I could obtain relating to hibernating animals, a portion of which I have given in part I, I undertook numerous experiments, to verify, as far as possible, what had already been observed, and with the hope of obtaining some new light upon the subject; the results of which research I have fully recorded in part II.

I have also ventured to give a new theory of the cause of winter sleep.
No one having searched the tissues at all minutely, for any changes which might occur in them during hibernation, I undertook this task; but, as no record of the minute anatomy of the hedgehog could be obtained, I had perforce to begin by studying the appearances presented by the various tissues during summer, that is, during that period of the year when these mammals most closely resemble other warm-blooded animals. This being done I was in a position to estimate the amount of the change, if any occurred, during winter sleep.

I have therefore given in Part III the histology of each organ with some detail, followed by the most obvious changes noticed in it.

At the end, I have gathered together all new facts into a résumé, to facilitate, as far as possible, the reading of this rather voluminous treatise.

Before closing, I have much pleasure in thanking Professor Rutherford, in whose laboratory the research has been entirely carried out, for his counsel and great kind...
new in giving me almost unlimited facilities for
the prosecution of the work; to Dr. Huxley I am
indebted for great assistance in the chemistry,
and for his kindness in verifying some of the
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E. W. Carlier.

Physiological Laboratory of the University
of Edinburgh. April 1891.
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Historical Sketch.

The prolonged condition of profound sleep termed hibernation, to which some animals are subject during the winter and spring months, attracted the attention of the ancients. It was known to the Greeks, and described by Aristotle; the Romans also knew that such animals existed but were not very familiar with them.

During the dark ages which followed upon the fall of the Roman Empire, science as well as art and all polite learning was ignored, none but the monk having any leisure to devote to the inquiry after nature; but with the fifteenth and sixteenth centuries the chaotic condition of civilization began to disappear, and out of the turmoil of arms arose the great nations, which at the present time are cultivating the arts of peace. Already in 1550 the Swiss naturalist
Gessner wrote a voluminous account of the animal kingdom, in which due attention is paid to hibernation. That the earliest modern account of these animals should come from Switzerland is only natural, owing to the inaccessible nature of the country, devastating armies were prevented from sweeping over the land, and owing also to the high mountains containing the marmot, one of the most conspicuous and interesting of the hibernating group.

During the time of Holland's greatest glory, Ruysch, about 1718, produced a history of the animal kingdom, superbly illustrated and written in Latin, but shortly after his time the conquering navies of England put a stop once and for all to any advance in the Netherlands.

The next great naturalist to arise was Buffon, who flourished in France from 1749 to 1788, he popularized natural history by his voluminous
and elegant writings in a language
that all could understand, and with
his, truly begins the literature of the
subject.

In the early part of the nineteenth
century, the Academy of Sciences of Paris
offered a prize for the best essay on
the causes of hibernation which was
competed for by Spallanzani and
Menzieri in Italy, and by Saisy and
Pouchelle in France.

In 1824, Edwards again took up the
subject in Paris, closely followed in
1832 by Marshall Hall with an elabo-
rate treatise on the subject, and by
John Hunter in 1847 in this country.

The subject now seemed to be exhausted
but after a lapse of twenty years
Valentin in 1857 reinvestigated the
subject at Zurich and added much
to what was already known; he
was followed in 1864 byWalther in
Germany.

Since 1872, many papers have been
published relating in one way or
Another to the subject of hibernation, among those who have written on this subject are: Holst in 1872 to 1882, Bartkoz 1876, von Doi in 1879, Bergamini 1881, Deniere 1882, Rosenthal 1882, Lamy 1882, Hoel 1888, Alexandre 1888 and lastly Dubois in 1889.

This closes the long list of eminent men who have laboured on the subject, a summary of whose work will be found in the next chapter.
Literature.

General characteristics of the
Hibernating Condition.

Aristotle, the Ancients and the
earlier writers of modern times con-

cluded their observations to the external
characteristics of the various animals which
they described, giving in each case the
more palpitant points of the hibernating
condition, and not in frequently dwell-
ing at considerable length on the shape
and the arrangement of the burrows
or other hiding places in which these
animals pass the winter.

Thus in 1550 Conrad v. Gessner (1)
speaks of Hedgehogs retiring into holes
in the ground, which they had previ-
ously stocked with fruit, leaves and other
vegetable products. In these holes
they pass the winter, rolled up in the
form of a ball. In speaking of the
Warm not he gives the exact shape of
the burrow made by this animal.

In 1718 Ruppel speaks of hedgehogs
passing the winter in holes in which
they lie as if dead.

In 1749, the great French naturalist
Buffon (5) gave a more detailed account.
Bats, he says, remain torpid during
winter, some cover themselves with their
wings as with a mantle, suspend
themselves from the roof of caves by their
hind feet and remain in that position.
Others adhere to the walls or hide
themselves in holes. Many individuals
collect together and by close contact
protect each other from cold, they pass
the winter without food, only awakening
in spring.

Domestic according to this author
are true winter-sleepers, falling into a
torpid condition when exposed to cold,
but if kept in a warm room they
pass the whole winter in a state of
activity. When they feel cold they hide
themselves in holes in trees and walls.
where they remain motionless rolled into a ball; when in this condition they may be handled freely and even rolled about without waking, heat alone, which must be gradually applied, causing them to awake; if heated too suddenly they die. Their eyes are firmly closed and they remain deprived of all use of the senses. The heart continues to beat however in a feeble manner, and the breathing is not suspended though feeble and very much less rapid than in summer.

Of the marmot he says that these animals hibernate in holes of peculiar shape, which he describes fully, but make no food provisions; they lie rolled up in an ovicular position in the hay of which they have been careful to cut and dry a sufficient quantity to form a soft warm bed at the bottom of their holes. During winter their circulation and peristalsis are almost arrested.

Spallanzani (4th) 1803 maintained
that animals do not breathe during hibernation and therefore require no oxygen.

In 1802 Mangili states that animals breathe during winter sleep, but only very slowly, and that a temperature of $5^\circ$ to $9^\circ$ Réamur is necessary, as cold awakens them, the circulation is not suspended but only enfeebled. Should the animals wake from any cause they take no food but live on the fat stored in their bodies.

He further states that one occasion he forced into a box of bats which were hanging from the roof of a cave, dislodging many without waking or injuring them, but that a bright light brought into the cave caused slight movements in some.

Dorvillé wake up regularly during hibernation to bathe food.

Saissel in 1808 gives the following characters as common to all hibernating animals observed by him.

The animals assume an oblique
position, their eyes are closed, their jaws clenched, their limbs stiff and cold.

The flexor muscles overcome the extensor muscles though these animals seem dead.

Their temperature is only a little above 0° Centigrade. Their respiratory movements cease and the circulation is arrested except in the chest, where pleuritic oscillations of the blood are visible; the blood vessels of the body are for the most part only half filled with blood, those of the abdomen and thorax alone being fully filled. The blood itself is liquid though cold and still. The fat of the body is not solidified, being only a little denser than in summer. The animals have no feeling and their irritability has disappeared except in the heart, but can be recalled by the application of adequate stimuli.

The condition above given is one of very deep hibernation.

Prunelle (9°) 1811.

According to this author hedgehogs become torpid at a temperature of 2° to
3° of Centigrade, they wake at intervals, take food with which their holes are stuffed, and then fall asleep again.

Bats and Marmots which breathe a little during winter sleep, and show slight movements of the heart, lose weight rapidly. The latter when paralysed or cut with a knife show no movement: the blood is of the same colour in both arteries and veins.

In another paper (96) he says that all animals do not fall asleep at the same temperature, nor sleep with the same intensity: hibernation can only occur at temperatures between 0° and 20° Centigrade. The secretions are much diminished, and the skin is covered with a layer of fat or pellicous matter which prevents evaporation.

Regnier the following points as signs of winter sleep:

An orbicular position, accompanied by stiffness of the muscles and loss of heat; added to these, there is an apparent cessation of the respiration...
with complete fasting.

In 1824 Edwards (6) wrote that during hibernation the animals examined by him were like cold-blooded animals, their temperature was pescilly above that of the surrounding atmosphere, they were to feel like reptiles, exhibiting only feeble and irregular respiratory movements repeated at long intervals, and during several months they took no food.

Marshall Hall (12) in 1832 after careful observation wrote that hedgehogs did not pass the whole winter in a continuous state of hibernation, but maintained that they awoke at intervals to take food and then fell asleep again. He also maintained that hibernation differs from ordinary sleep in this, that the breathing is impaired, that the evolution of animal heat is altered, that there is an increased power of learning the withdrawal of air, that the blood is venous, and that the left heart is vero-contradite swing
to an increased irritability of its fibre.

He also distinguished between torpor and hibernation; the former being due to excessive cold, the latter being induced by a moderately low temperature; excessive cold causing the awakening and subsequent death of the animal.

Barkow (14) in 1846 was the first to discover that the body weight of hibernating animals does not diminish, but remains constant or tends to increase slightly. He also observed that an animal might be cooled to -2° centigrade without being injured or awakened.

Valentini (16a) 1857 to 1881.

Marmots do not hibernate at all readily in captivity. In the wild state their winter sleep is very deep, they may be dug from their holes, put down the mountain by post or transported by rail without waking, or if they should be awakened by the getting to which they are subjected they quickly fall asleep again when placed in a suitable temperature.
The eyelids are then closed, the pupils dilated, and if the sleep be deep, no respiratory movements occur for several minutes at a time; when the sleep is less deep, faint wave-like respiratory movements may be observed.

During a condition of profound hibernation operations may be performed on them, such as the ligation of vessels, the dissection of nerves, etc., without waking them; a bright light thrown into the eye by a condensing lens, or a pistol discharged close to the ear remains without apparent effect; ammonia however, when applied to the nose causes them to awake after a short time. They are more sensitive to mechanical stimuli, such as pinching the cavities of the nose and pharynx with a glass rod.

Marmots wake up at long intervals to urinate and to defecate, the length of the interval depending on the depth of the sleep. An interval of one month is common, or even of six weeks, an interval of two months was
observed in one case. The intervals are
shorter during the first part of the
hibernating period than towards the
end. After voiding their excrements
the animals remain awake for some
time, but in the course of a day or
two, they again become lethargic.
Hedgehogs on the other hand are
easily disturbed being only very light
sleepers.

Hibernation in marmots can be regulated
artificially by varying the temperature,
they usually fall asleep as soon as the
temperature falls to 10° or 5° centigrade.

Atmospheric pressure and the hygro-
metric state of the atmosphere have no
influence on hibernation.

He further states that hibernating
animals lose weight steadily, though
somewhat irregularly, and that the
fat and hibernating gland are used
up during the first half of the winter
sleep. Breathing and interchange of
gases is very slight and animals may
be cooled to -20° centigrade without injury.
Horvath (82) 1872 – 1882.

This author found that the zeigel which he used breathed during hibernation, but only two or three times a minute, and could be cooled artificially to 1°8 Celsius without injury.

The zeigel is not a continual sleeper as is usually supposed, never waking up during the whole period of hibernation, but on the contrary waking every fourth or fifth day to eat. He has also noticed that some 3 zeigels fall into this condition during summer. The age of the annual makes no difference in the period at which it naturally begins to hibernate.

This annual when lethargic appears as if dead or dying, but wakes up on being handled; when undisturbed it frequently changes its position from one side to the other, but never lies on its back, though it often assumes this position during ordinary sleep. It never micturates, defecates nor emits any sounds during the whole period, though
its kidneys are secreting urine all the time. The sphen muscles are excitabile because when it changes its position, the hair, on the side on which it had been sleeping, quickly rises up. Lind poodles have no effect on it, from which the author concludes that it cannot hear, the eyes are closed and nothing will induce the animal to open them, the eyelids are very firmly pressed together, it being difficult to force them open; but when this has been accomplished, they close again with a snap. This he thinks is the best test for ascertaining whether an animal is hibernating or not.

Drumke (25) 1882. agrees with Valentii as to the phenomena presented by hibernating animals. He speaks of the orbicular position, the closed eyes, the pluggish and shallow respirations, and the want of great reaction to external stimuli, as being characteristic of the condition.
The marmot, which he studied, falls asleep at a temperature which varies between 4° and 12° centigrade, the average being 7°; it makes a bed of hay and covers itself with the same material, thus forming a chamber which is heated by radiation from the animal's body. The body temperature is always two to four degrees above that of the air of the room in which it is kept, a fall of the body temperature causes an increase in the depth of sleep.

He observed that all his animals awoke from time to time to void their urine and feces, after which they quietly fell asleep again. Some marmots are not as a rule subject to winter sleep.

In 1882 Rosenthal (24) wrote that no bird is known to hibernate, but that mammals which are subject to this condition fall into it as soon as the external temperature becomes as low as 8° or 5° centigrade,
and that during this condition their body heat is almost always above that of the atmosphere, sometimes equal to, rarely below it; they are not able to follow rapid changes of temperature and great cold awakens them, as does also external irritation. Their respiration is slight, accompanied by very little gaseous interchange, and their heart-movements slow.

Florel (26) 1888.

This author experimented with fat dormice; he thinks that decrease of external heat is not alone sufficient to account for hibernation. When irritated his dormice showed some reflex movements and squeaked slightly. He placed one of them on the top of a Christmas tree, as soon as the animal touched the branches with the pads of its front feet, a reflex contraction took place and the animal remained hanging for some time; gradually the paw unclasped but the animal did not
fall, as, before it relaxed its hold with
one foot it caught the next lower
twig with the other paw and remained
again suspended for a little time.
In this way the animal gradually
climbed down the tree until it slow-
ly reached the floor, where it continued
to sleep quietly.
Hovel is of opinion that this condi-
tion partakes of the nature of hypnotic
sleep and recommends hibernating
animals for hypnotic experiments.
Buffon (3) attributes the hibernating condition to a cooling of the blood, as these animals possess little body heat, the addition of heat from the sun is necessary for their active existence. Spallanzani (4a) believes that the state of rigidity into which their muscles fall, is the cause of winter sleep.

Cleghorn (6a) maintains that the mephitic condition of the air in their holes, where it is with difficulty renewed, is the true cause.

Alibert (7) thinks that this condition is due to a filling of the cerebral vessels with blood.

Mangili (5b) mentions that the above conditions are insufficient of themselves to explain winter sleep, even if hunger be added to them; he looks rather for some anatomical peculiarity in these animals, and finds that the blood vessels of the
brain differ in size from those of
the rabbit, guinea pig, etc., and con-
ccludes that the paucity of blood sup-
ply to the brain, coupled with absen-

cence and cold, is the true cause.

Sauvy suggests that hibernation
may be brought about by want of
air, but believes that the general
anatomical structure of these ani-
imals renders them very susceptible
to cold, and that this taken in
connection with the small size of
the lungs, as compared with the
size of the heart and blood vessels
of the liver, the tenuity of the
capillary vessels of the skin, the
large size of the cutaneous nerves,
and the sweetness of the bile, may,
in a great measure, account for
the hibernating condition.

For owing to the large size of the
cutaneous nerves these animals feel
the first colds of winter very acutely,
which causes contraction of the cuta-

caneous filers, erection of the priees and
hairs, and drives the blood from the
thin into the deeper parts. The
animals too remain passive, which
causes a diminution of the respiration,
which in turn causes a lowering of
the body heat and a consequent slow-
ing of the circulation.

When the cold becomes more intense,
these phenomena are increased,
the skin thickens and becomes
hard, the animals cease to eat,
and the consumption of oxygen
diminishes; the animals are only
saved from death by the blood
remaining fluid, by the gradual
preparation which they undergo and
by the body temperature never fal-
ling below zero centigrade.

Prunelle (4) lays stress on the
fact that the thorax is filled du-
dring winter with various gland
masses and fat which by their
presence prevent the free play
of the lungs. In Autumn the
animal feels a fullness which
makes it desire repose in a warm sunny place; the large quantity of nerves with which the placid is supplied makes it readily feel cold. He compares it to an obese person who always feels inclined to sleep. The circulation in the extremities becomes retarded and the blood accumulates in the abdominal and thoracic vessels, which is more rapidly brought about if all causes tending to excite the animal to movement be eliminated.

Hibernation begins as a penmiveness, which differs from ordinary sleep in its slow onset, which is quickly followed by complete lethargy.

By the oblique position which all these animals assume, the claws and sternum come to press on the neck, constricting the trachea and preventing free access of the blood to the brain, which acting less vigorously sends more feeble stimuli to the intercostal muscles,
whereby their movement is diminished. The accumulation of fat in the abdomen also prevents the free play of the diaphragm, so that the lungs are less expanded than during the active state of the animal.

This is the author considers the first stage. The second stage is brought about by alteration in the insufficiently aerated blood which further diminishes the activity of the brain, and the heart receiving a less stimulating fluid begins to beat more slowly and feebly, only maintaining a circulation of the blood in the thoracic and abdominal vessels; the limbs, being thus deprived of blood become rigid and cold. If this condition went on progressively, the animal would inevitably die, but the interchange of gases in the lungs is never quite arrested, and as hibernation goes on the fat and glands are slowly removed to nourish the animal, by which means a gradually increas-
ing chest capacity is obtained.

The author wishes to substitute the term "incomplete asphyxia" for the term now in use to designate the hibernating condition.

According to Edwards (10), hibernating animals do not differ from others in their anatomical structure, but produce less heat in spring and summer, in consequence of which their temperature falls in the fall of the year. These effects are produced by the deficiency of nourishment, the long fast resulting in a languor approaching to death.

Lowness of the external temperature is presumably the immediate cause of winter sleep, as they cannot produce sufficient heat to counteract its effects.

Valentin (16a) states that quiet is the chief necessary factor in winter sleep.

Hovath (18c) says that true winter sleep cannot be produced artificially
by cooling hibernating animals, and that it cannot be traced to any anatomical or physiological difference between them and others. No one knows anything definite about this condition, a physiological or an anatomical basis for it has only rarely been sought, and has led to no results. That animals can lie for weeks without food and with a low body temperature is not applicable to any known scientific theory, not even if we admit that they live on their own fat, for fat alone is not sufficient to maintain animal life.

Puricke (2) agrees with Valentini and pays, that the external conditions of rest and suitable temperature, although necessary, are not the true causes of hibernation, which must be sought elsewhere.

When the process of falling to sleep is studied with the thermometer, we find that there is a preparatory
stage—lasting several days, during which the body temperature gradually
rises to 33° or 35° centigrade; at
which temperature it remains const-
stant for several days, followed in
about 48 hours by a sudden fall.

He tried to produce artificial
hibernation by the administration
of chloral, but found that the drug
had very little effect upon the ani-
mals (marmots) which he used in
these experiments; when under the
influence of the drug, they became
relaxed, spread out and drowsy, but
their temperature was never lowered.

Nord (26) says that winter sleep
cannot be due to decrease of tempera-
ture alone, as two fox dromice in
his possession began to hibernate in
June and July, when it was very hot,
but insists that it is of the nature
of hypnotic sleep.
The Causes of and Phenomena which accompany the Cessation of Winter-Sleep.

Buffon (1) says that hibernation ceases with the cause; when the cold of winter gives place to the warmth of spring, and the temperature rises to 10° or 11° Réaumur, the animals awake. They can be caused to awake at any time by gentle warmth.

According to Mangili (2), the animals may wake from some cause or other, during the winter sleep; when this occurs, their store of fat is of service as they eat no food; they may be awakened by a sudden or a gradually increasing cold, for, bats which he bore from a cave in which they were hibernating, and placed outside on the snow, soon woke up and flew back again.

Dormice wake now and again from hunger and take food.
This author caused an animal to wake by warming it and observed that when it began to walk, the hind limbs were dragged after it, from which he concludes that the anterior part of the body is the first to wake after an increase of the respiratorv movements has taken place.

Süssmayr made experiments to ascertain the time taken by hibernating animals to wake up, and found that marmots take from 8 to 9 hours, hedgehogs from 5 to 6, bats from 3 to 4, and dormice, which are very light hibernators, only about 2 hours.

A gentle heat is not necessary to awaken these little animals; a little shake, a slight irritation, or a short exposure to a colder temperature than that at which they fell asleep, is ample; when caused by any of these means, if left alone they again fall asleep in from 18 to 20 hours. Dürmelle (92) states that during the
Torpid state they wake at intervals, and this occurs as soon as the temperature reaches 15° to 17° Centigrade. He made an incision into a rigid hibernating whose temperature was 10° Centigrade, which soon caused it to awake, its temperature rising to 36°.75°. An other animal placed in an ice house quickly awoke, both good and remained lively.

Of bats he says that when brought into a warm room they at once begin to breathe, and in a few hours are flying about, if placed quite near the fire, they wake in fifteen minutes. Cold causes them to wake; he placed a bat on the window-sill in winter when the temperature was -30.22 Centigrade, and found that it showed signs of life in four hours and before next morning had flown away. Currents of air readily make these animals, no matter at what temperature, perform experiments by blowing
on them with bellows.

Marmots wake when the temperature reaches 20° centigrade and by the time it has risen to 25° they are quite lively, one stimulated with Volta's pile began immediately to breathe and in fifteen minutes its temperature had risen to the normal summer height.

It is maintained by Marshall Hall (12) that hedgehogs wake now and again from hunger, and when they have eaten they fall asleep again. Cold applied to them causes, first a waking, followed by torpor and death; cold water poured upon them will neither wake them, nor cause them to unroll. Sudden waking is dangerous to these animals as the irritability of the heart is too great.

Valentini (162) observed that the hedgehog is easily roused by all kinds of mechanical stimuli, but that in the case of the marmot they act much less readily, except cur-
cents of air which make them very poor. Ammonia or turpentine applied to the nose and mouth causes them to move in about half an hour. They naturally awake at long intervals to urinate and defecate; this occurs more frequently during the first half of winter sleep than at a later period.

According to Haeckel (186) Geiżel wake every four or five days from hunger; they are easily raised by the warmth of the hand and permanently wake up in February.

He made many experiments, about twenty in all, to ascertain the variations in the body heat during the process of waking. The animals were stimulated by pharmacological electricity and awoke slowly; he denies that animals so treated ever wake up suddenly. One of his experiments is here given.

A hibernating Geiżel whose body heat was 8° Celsius at starting, had
the pads of its feet paraded. The temperature of the air was 9° or 10° Celsius. During the first hour, the temperature of the rectum rose 2°, during the second hour 5°, and during the subsequent half hour 15°. This more rapid rise began after the body heat had reached 15° to 17° Celsius. In the next forty minutes, it had risen from 17° to 32°. This rapid rise of the body temperature is opposed to all known physiological laws.

The respiratory movements were also increased in frequency. There were nineteen a minute at the beginning of the experiment, after fifteen minutes, they were to twenty-three, after thirty minutes, to fifty, after fifty minutes, they had fallen to forty-five, and after one hour, they had further fallen to forty per minute.

Two hours after the beginning of the experiment, the animal got
up on its fore legs, opened its eyes, and began to eat.

He believes that during the commencement of the process of awaking the circulation of the blood limbs is completely interrupted.

Limeker (22) observed that movement and reaction to stimuli occurred in waking mammals at a much lower temperature than that at which they ceased in the same animals as they were entering into the hibernating condition. His animals often woke during winter sleep to void their excrements, which he attributes to the contents of the bladder acting as internal stimuli.

To ascertain the amount to which the body temperature rises during the actual period of waking, he made many experiments of which one or two are here given.

An animal in the hibernating state was brought into a room the temperature of which was 14° centigrade, and
its feet paralysed, with the result that its temperature rose in two hours forty minutes, from 9.6 to 25.0.8 centigrade in the pharynx, and from 9.7 to 28.5 in the rectum. At the end of four hours and forty minutes the temperature had risen to 34.0.5 in the rectum.

Another animal in a similar condition was brought into the same room, but the heads of its feet were not paralysed; at the end of six hours fifty minutes the temperature in its rectum had risen from 7.8 to 12.6, and in its pharynx from 8.0 to 12.9.

In another experiment he cut the spinal cord of the animal at the level of the 4th dorsal vertebra, stimulated its feet with an induction machine, and found that after five hours twenty-five minutes the temperature of its rectum had risen from 7.7 to 34.0.9, and that of its pharynx from 7.8 to 33.2. The animal was then replaced in the cold room from which it had been taken, but its temper
nature continued to rise for two days, at the end of which time it was 35.01 and 35.07 respectively.

These experiments show that a hibernating marmot may maintain a lower temperature than that of the surrounding air for six hours, due perhaps to the fur acting as an air jacket, preventing radiation; that animals under the influence of mechanical stimuli, as well as that of heat, may regain their former temperature in five hours, and that animals whose nervous system is left intact regain their former temperature more quickly than those in which the cord has been severed.

Another series of experiments were undertaken in a cold room with the view of eliminating the action of external temperature, with similar results.

During all these experiments, the respiratory movements gradually increased in rapidity.

Rosenthal (21) states that as soon as
Hibernating animals are passed their
body temperature begins to rise and
quickly attains a maximum; when
wakened by irritants, the body heat
rises very quickly, but falls rapidly
also if the irritation be not too prolonged,
so that in eighteen to twenty hours they
fall asleep again. The heating proceeds
more quickly in the anterior than in
the posterior half of the body. The
awakening is always preceded by an
increase in the respiration, and heart
beats; this would be enough to account
for the slight rise of temperature
which occurs during the first hour;
loss of heat during this time being
very slight as the skin remains cold.
The thesis doubt on Paniche's experi-
ments in which the spinal cord was
perverted.

To see whether the statements of
Paniche were correct with regard
to distention of the bladder being the
cause of awakening, Dubois made
a fistulous opening into the bladder
of an hibernating animal, through which the urine was allowed to escape by a tube. The animal fell asleep after the operation and remained in a state of torpor for several months, at the end of that time passing insensibly from quiet sleep to death.

From this experiment he concludes that the accumulation of urine is the true cause of the periodic resumption of the phenomenon of hibernation. Variations in temperature, pressure, and amount of water vapours, magnetic and electrical disturbances have no influence on the awakening of marmots; neither is it due to excitement of the medulla by accumulation of carbonic acid in the blood, as this would be in distinct antagonism with what is known concerning the state of the blood during hibernation.

He concludes that hibernation resembles very closely the condition of an animal after section of the medulla oblongata.
Respiration.

According to Buffon, the domoise breathes freely during winter sleep. Shalawzani (27) placed a hibernating marmot for 3½ hours in a pneumatic-chemical machine filled with ordinary air, at the temperature of -12° centigrade. The animal remained still as a stone, and during the whole duration of the experiment, the level of a mercury manometer attached to the instrument did not vary. He analyzed the air of the chamber and found that it did not differ in the slightest degree from the air of the room in which the experiment was performed. He concludes that during 3½ hours the animal had not breathed.

An animal placed in the same machine at a temperature of 0° cen began to exhibit slight respiratory movements, but did not wake. So very the experiments he placed the first animal in the machine.
while he had previously filled with carbonic acid gas, kept at a temperature of -12.5°C. With the lethargic marmot was a rat which died in three minutes, but the marmot remained in the machine for four hours, and when taken out and exposed to a temperature of 0°C for a short time began to breathe, therefore it had not been killed by the carbonic acid.

The same animal was again placed in the same machine filled with carbonic acid gas, but maintained at a temperature of 0°C. This temperature is not sufficiently low to produce complete lethargy in the marmot, slight respiratory movements occurred with the result that the animal soon died.

He concludes that hibernating animals when fully asleep require no oxygen and therefore do not breathe; it is only on waking slightly that they begin to require it.
Mangeli (52) found that the respiration increased on exposing an animal to cold. He placed a leathern jacket moistened over live water in the chamber of an air pump and left it. The air of the chamber was used up little by little, a puffy white pellicle becoming visible on the surface of the fluid; on testing the air he found that it had lost oxygen, and that the pellicle consisted of carbonic carbonate.

Another animal in a deeply hibernic condition was seen to breathe rhythmically, but only about fifteen times an hour, instead of fifteen hundred times, as in summer.

He observed that in the hedgehog (56), the respiration is suspended for fifteen minutes at a time, followed by thirty or thirty-five respiratory movements; when the temperature comes a little the animal breathes seven or eight times every eight minutes; artificial cooling quickly causes a decrease in their frequency by lengthening the
pause. This animal only breathes five or six times a minute during ordinary sleep.

Bats breathe very slowly and at rare intervals when torpid. He placed some on paper when their respiration quickly increased.

Dormice breathe 22 to 24 times, then rest for 4 minutes, after which they again breathe 22 or 24 times, exposure to cold lengthens this interval. Another brand of dormouse has an interval of 4 to 8 minutes followed by 21 to 30 respirations, with cold the pause may be lengthened to 12 or 13 minutes.

Sainy placed a hibernating mouse in a known quantity of air, which he tested every fifteen minutes to ascertain the quantity of oxygen used by the animal, and concludes from various experiments performed both in torpid and active animals, that they require a considerable quantity of oxygen during activity, that this amount diminishes with the temperature, that when torpid they
can live for a time in an atmosphere which is unfit either for combustion or respiration, that when the respiration are only just visible the quantity of oxygen consumed is very small and that in deep winter sleep no oxygen is used at all, there being no respiratory movements.

He counted the frequency of the respirations in summer and in winter and made experiments by placing animals in water and by opening one side of the chest, to observe the expansion of the lungs, and found, that their breathing is short and quick in summer, slow in autumn, almost suspended in incomplete hibernation, and absent in profound torpor.

Perrinelle (98) plunged a lethargic hedgehog into water at 10° centigrade, and kept it there for 4 minutes, without any bad effects. But, which do not breath when hibernating, but in which the respiration becomes visible as soon as they are brought into a
warm room, were placed by their sides in water, one dried after 20 minutes immersion, the other which was withdrawn in 6 minutes took no harm.

He placed two of these animals under a bell jar over lime water, taking care to get rid of all carbonic acid before doing so, in this he kept them for 10 days, at the end of which time one died, the other though still alive was very ill, and died soon after being withdrawn. The fluid was covered by a thick scum of calcium carbonate. On another occasion he placed one animal in the pneumatic machine and exhausted the air, it soon died.

Dormice like bats breathe irregularly when the temperature is somewhat high, but during 10 for they are still as stones.

A hibernating dormouse placed over lime water in a pneumatic machine for 2 1/2 hours, was still alive at the end of this time, the air of the chamber contained 9.16% less oxygen than...
that of the room; three days after
the animal died in the chamber, the
air of which was by that time devoid
of oxygen, but much calcium carbonate
had been formed.

A lethargic marmot showed respira-
tory movements when the temperature of
the air was 12.5°C, but they were too
feebly to be counted. They only became
distinctly visible when the temperature
rose to 15°C but were still intermit-
tent. They did not become regular
till a temperature of 22°C was reached.

A hibernating marmot placed in car-
bonic acid gas died in 12 minutes, one
placed in air containing much oxygen,
awoke in a few hours.

The air exhaled by a hibernating mor-
mot contains more oxygen than that
exhaled by a similar animal in the
active condition. If two animals
placed in bell jars at different tem-
peratures, the one which was warmed
used more oxygen.

Respiration though much diminished
is never quite suspended during winter sleep, as is shown by all animals placed in carbonic acid gas, dying.

According to Edwards (10) the respiratory movements during hibernation are irregular, feeble, and occur at long intervals. These animals in summer would generally die from want of air if placed in water, but in winter, he found that bats may remain in it for 4 or 5 minutes without hurt.

In summer the respiratory movements are lively, in autumn slow, and in hibernation may cease altogether, with no loss of life. Great cold excites the respiration.

Hibernating animals, while producing less heat and consume less air than other mammals, experience a sensible alteration in their respiratory movements from a degree of cold which would have no effect on the system of other animals.

Marshall Hall (6) finds that in the hibernating animal the respiration is impaired during hibernation, and the animal when placed in a pneumotachy causes little alteration
in the air, in fact the respiration is very nearly suspended, no visible motion of the chest wall being present, it can support almost total absence of air.

He attached a writing style, which moved on an index to the chest wall of a bat; turning it for the style did not move at all, if the animal was irritated. However, the style began to move. With the hemoglobin he obtained the same results, the animal on being stimulated giving a few deep, porous respirations, which ceased at once if it be no further molested.

With the pneumometer he found, that practically, no gases were absorbed by lethargic animals, the very slight absorption which did occur, he believes to have taken place through the skin, perhaps a slight diaphragmatic breathing also occurs. This author kept a bat in water for 16 minutes, and a hedgehog for 22 1/2 minutes without bad results; in summer the latter animal would under such conditions
die in three minutes; from this he concludes that such animals can bear asphyxia during hibernation with comparative impunity.

Regnauld and Reiset (13) experimented upon marmots which had ceased to hibernate before they arrived, and their results correspond to this condition of the animals.

Valentini (16) in an elaborate series of experiments demonstrated that the marmot hibernates as readily at an elevation of 6000 feet, as at the sea level, and by rarefying and condensing the air, showed that hibernating animals were not awakened in an atmosphere of only 9 millimeters mercurial pressure, or in one the pressure of which was equal to 3 atmospheres. They ultimately make in rarefied air owing to deficiency of oxygen.

He criticizes the assertions of all who preceded him, and to ascertain the points which he maintains, he experimented on 50 marmots and 16 hedgehogs.
He estimated the amount of gas by the endoscopy, and observed the frequency of the respiratory movements by the oscillations of the mercury in all cases, except in the deepest lethargy, when the movements are too feeble to be seen. He maintains that frequency of the movements is no criterion of the respiratory activity as they vary considerably in intensity and appear at varying intervals.

The following table gives the average amount of carbonic acid excreted and of oxygen used, per kilogram of body weight per hour, for various intensities of sleep:

- Deep sleep: 0.0144 gms CO₂, 0.0238 gms O₂
- Less deep sleep: 0.032...0.047...
- Light sleep: 0.125...0.144...
- Half awake: 0.569...0.575...
- Awake: 1.076...0.973...

In summer the mouse excretes 75 times as much carbonic acid, 20 times as much water vapor, and uses 41 times as much oxygen as in hibernation.

The quantity of oxygen absorbed in sum-
iner is considerably less than that of the carbonic acid produced, the animals agreeing in this respect with other mammals, but during hibernation the reverse of this obtains.

The hibernating gennet produces 20.5 times as much carbonic acid, and uses 18.4 times as much oxygen as during winter sleep.

In deep sleep the respiratory movement and heart-beats do not show a mutual dependency; inspiration lasts as a rule longer than expiration, followed by a longer or shorter pause.

Herbaux (82) states that the gennet during the lethargic condition, its experiments on the variation of the respiration during the process of waking have already been given.

Hibernating gennets produce, at 9°C, can degrade, 0.015 grams of carbonic acid, and 0.014 grams of water vapour per kilogram of body weight per hour; during
activity at 18°.5° C, the same animal produced, 0.5-13 grams of carbonic acid and 0.098 grams of water vapour.

Dorr (202) follows Regnard and Valentin and states that the interchange of gases in deeply sleeping mammals is very small, and that only 44% of the oxygen taken up reappears as carbonic acid. He gives Varanis's experiments in support of this. Dorr (232) states that during the process of waking, the respirations increase.

Rosenthal (224) points out that hibernating animals consume very little oxygen and produce very little carbonic acid; after waking, much carbonic acid gas is evolved. He must believe that the oxygen taken up during active life is only used up to a very small extent during winter-sleep, because the oxygen consumed is reduced to a minimum during this condition. Owing to the same respiratory movements a smaller supply of oxygen is sufficient to cover the demand. Awakening is preceded by increase of
respiration.

Erntz (28) states that hibernating animals are an exception to the homeo-
thermal animals in having a remarkably
low value for their respiratory quotient.
Can only be explained on a theory of
their accumulating oxygen or incom-
pletely oxidized substances in their
bodies.
Animal Heat

Domestic according to Buffon (3), have no little internal heat, that their body temperature is not much above that of the air, that is to say about 10° Réaumur. He ascertained this by means of a thermometer.

Pallas (6) maintains that the blood of animals which hibernate is a little colder than that of other mammals, that their temperature during activity is almost as high as that of man, and that their body heat is directly proportional to that of the atmosphere.

Sauzay (8a), who paid great attention to this subject, and who studied the temperature with the thermometer, gives the following table:

<table>
<thead>
<tr>
<th></th>
<th>August: Temperature of Air 22° C</th>
<th>September: Temperature of Air 19° C</th>
<th>November: Temperature of Air 7° C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marmot</td>
<td>36°5 - 38° C</td>
<td>51°2 - 57°6 C</td>
<td>27°2 - 34° C</td>
</tr>
<tr>
<td>Hedgehog</td>
<td>35° - 36° C</td>
<td>33° - 34° C</td>
<td>15°7 - 15° C</td>
</tr>
<tr>
<td>Dormouse</td>
<td>36°5 - 57°5° C</td>
<td>31° - 36° C</td>
<td>21° - 23° C</td>
</tr>
<tr>
<td>Bat</td>
<td>30° - 31° C</td>
<td>28° - 29°7 C</td>
<td>12° - 14° C</td>
</tr>
</tbody>
</table>
which show that those who say that the body temperature of these animals never exceeds 10° are wrong.

January Temperature

Marmot: 7° - 8° C

Hedgehog: 3° - 4° C

Shrew: 2° - 3° C

Bat: 4° - 5° C

This table shows that the temperature of these animals follows that of the atmosphere, remaining however always a little above it at all times of the year. The greatest cold of winter never lowers it to 0° C. If hedgehogs be cooled artificially to 0° C or below, they invariably die.

The author made many experiments to determine the degree of cold necessary to produce hibernation in these animals. He found, the marmot resisted artificial cold of -10° C for a considerable time, but after 24 hours exposure to this low temperature it became lethargic. A temperature of 7° C causes lethargy in the hedgehog, of 5° C in the case of the bat and dormouse. This low temperature must be main-
Tamed for several hours to produce profound torpor.

Prunelle believes that hedgehogs begin to hibernate as soon as the external temperature has fallen to 2.5°C, their body heat in summer, measured in the mouth, being 35° to 37.5°C. On making an incision into a hedgehog, the temperature of which was 10°C, he found that the body heat quickly rose to 36.75°C, and the animal awoke. He cooled one of these animals to -15°C, at which low temperature it died.

Of bats he says that their temperature during lethargy varies between 5° and 19.5°C. In the case of one which he operated upon, the body temperature quickly rose from 6.22°C to 38.75°C.

The internal temperature, which varies somewhat in different parts, is always a little higher than that of the surface.

The temperature of the marmot during activity is 37.7°C, in winter sleep it varies between 6.2°C and 18.7°C, that of their holes
from 7.5 °C to 8.7 °C. A torpid marmot with a thermometer in its rectum was placed on a plane, its temperature quickly rose to 30 °C in 2.5 minutes, but when replaced in a cool chamber for two or three hours, its again fell nearly to what it had been at the beginning of the experiment.

An active marmot placed in a freezing chamber began at first to doze, but soon became uneasy and died in 10 hours.

He found that one necessary condition for the occurrence of hibernation was a temperature between 0 °C and 20 °C: the summer temperature of all animals which hibernate is from 35 °C to 38 °C; the winter temperature 2 °C above that of the surrounding air, but never falls below 5 °C. The body heat is in direct ratio with the amount of oxygen consumed by the animal.

Edwards, who criticised all who preceded him, cooled a bat by artificial means during the month of April and found that it lost 20 °C of its body heat. Guinea-pigs treated in the same
Manner only lost 2° or 3° C.

Cold-blooded animals, hibernating animals, and mammals form, according to this author, an ascending scale in heat-producing power; animals which hibernate having the power of supporting a degree of cold that kills ordinary mammals. Mammalian young, however, for a time resemble hibernating animals in this respect, their capability of supporting the reduction of temperature being inversely proportional to their power of producing heat. The production of heat in all mammals varies somewhat with the seasons; more heat-producing power is displayed during winter than in summer; in animals that hibernate this is not the case; they produce less in winter than in summer; bats producing least and mammals most.

Ordinary mice rank low in the heat-producing scale, being able to pass the winter only in a warm nest; they do not however truly hibernate.

The temperature of the hedgehog when
active, according to Marshall Hall, is 95° Fahrenheit, during hibernation it varies between 42° F and 43° F. The determined by placing a thermometer with elaborate precautions under the epigastricum of a bat that the body heat during January and February followed that of the atmosphere.

The maintains that young animals were incorrectly compared with animals which hibernate, as the latter maintain their own temperature; they have therefore full power of evolving heat. The loss of this power is an induced condition observed during ordinary sleep in all animals, though in a less degree than in true lethargy. It is further obvious that a due distinction is not made between hibernation and the torpor which may be produced by cold in any animal, especially if young.

John Hunter performed many experiments upon dormice, cooling them with a mixture of ice and salt, and concludes that in all cases the animals died before...
becoming frozen, that there was an expenditure of animal power in resisting the effects of cold, proportional to the necessity. Having made an incision into the abdomen of a dormouse and introduced a thermometer, he found that the mercury rose to 80° Fahrenheit, the temperature of the air at the time being 50° to 60° F.; he then subjected it to a temperature of 15° F. for a quarter of an hour, and found the mercury at 85° F.; again cooled for 15 minutes, the mercury which had fallen to 72° quickly rose to 85° F., replaced in the cold for 30 minutes, the heat in the pelvis was 62° F., that of the diaphragma 85° F. He repeated the experiment with other dormice with similar results. He then asked Jenner to experiment with the hedgehog, and concludes from their conjoint labours, that animal heat is increased under the influence of cold whenever there are actions requiring heat, to be performed; he suspects that the evolution of heat may have been due to the wound.
Cold acts as a pedative, all active functions being diminished by it; beyond the point at which these functions can still be performed, it acts as an excitant, stimulating the animal to move itself. Valentin (6a) confirms the observations of Savory (4) Barker, and Mangeli (5), and states that the temperature may be lowered during hibernation to $-2^\circ$C, at which point the animals begin to wake. In summer they behave like other warm-blooded animals. He sets forth many experiments to support his views. He has also given very elaborate tables of the temperatures of the various organs in hibernating mammals, comparing them with the external temperature; and concludes that their general body heat is $1.03^\circ$C higher than that of the atmosphere.

In treating of animal heat, Walther states that: 1. Artificial respiration can restore heat to a rabbit cooled to $18^\circ$ or $20^\circ$ centigrade, and this is only successful when the atmospheric temperature is not more than 2 or 3 degrees below that of the animal.
2. When cooled to 25°C the rabbit may by its own heat regain its normal condition of 38° to 39°C, but takes 8 hours to do so. The increase of heat produced by the respiration is very small.

3. A rabbit can be deprived of its body heat much less quickly than a hibernating animal, which therefore offers much less resistance to the abstraction of heat than the non-winter-sleepers.

4. A winter-sleeper is, under much less favourable circumstances, heated in half an hour by its own heat production much more than a rabbit in 12 hours.

5. A hibernating animal always contains more heat units for its weight than a rabbit. Heat production is therefore much greater in the former than in the latter.

6. The means which the organism possesses to counteract the loss of heat, the contraction of capillaries and spaces at the surface of the body, and diminished rate of heart-beat, both these mechanisms are self-regulating.
7. The influence of heat withdrawal varies for different parts of the nervous system, causing a loss of balance in it.

8. The lowest temperature to which a rabbit may be cooled and recover by its own heat production is 18° or 20°C. The possum may be cooled to 4°C and can reheat itself easily to 37°C, even when the external temperature is only 10° or 12°C.

In active zebras according to Kostal, the temperature is similar to that of other mammals, about 35° to 37°C. During winter it approaches to that of the environment, sinking as low as 2°C. He made many experiments on animals which were awakening from winter sleep as detailed elsewhere, and he compares them with dogs and rabbits.

A dog poisoned by strychnine may be heated, at the rate of 4°C in 25 minutes, by stimulation of the feet and artificial respiration. A rabbit cooled to 20°C, did not regain any heat, despite energetic artificial respiration, so long as the cu-
In winter, the temperature was kept at 20°C. In cases where a rapid rise of temperature always occurs and must be looked upon as a constant phenomenon, the animal can certainly maintain a constant temperature, but that it can
undergo very unfavorable circumstances without rapidly producing a great amount of heat is remarkable; and
and appears still more so when we consider that the two principal sources of heat, muscular movement and respiration are almost absent, finally the theory of stored up oxygen cannot be held in this case, as the animals had been exposed to the experiments in profound hibernation, taking up very little oxygen. These statements are directly opposed to the theory of animal heat, but are certainly cons-
tant. The author cannot find any explanation.

Thirty experiments made on zebras and hedges by artificial cooling show that
Hibernating animals readily undergo a powerful cooling of their bodies to even 1° C., and come round again, without the aid of artificial respiration or external heat.

In no case the temperature of a tropical jelly fell 2° C. below that of the air, which he thinks may be due to evaporation taking place from the surface of the body; he has often seen it 1° C. below and thinks this may be owing to the impossibility of following rapid changes of temperature. 

Annual heat being only comparatively slowly evolved.

Experiments made by cooling other hibernating animals both in summer and winter show, that they may be cooled repeatedly to -10° C. and recover, and that they are never subject to tetanus during the cooling process, as occurs in the case of rabbits; the heart also continues to beat rhythmically.

Owen who agrees with Valentini states that the temperature of animals during hibernation is always from 2° to 4° above
that of the atmosphere. That the temperature in the rectum is less than in the pharynx, the difference being 0.1 to 0.2°C at very low temperatures, the usual difference being of 1° or 2°, during the process of waking, the difference may be as much as 12° between the two. In the process of falling asleep, however, the difference is only 1° or 2°C. Mammals in the waking condition often show subnormal temperatures, such as 34° or 36°C, and their temperature may rise to 40° or 41°C, so that there seems to be a wider range in their temperature when awake, than in that of other mammals.

The author made many experiments to ascertain the increase of heat which occurred during the process of awakening from inactivity, and concludes from them that the temperature of these animals is during hibernation absolutely dependent on that of the surrounding atmosphere. Apparent deviations may be explained by the fact that the animals cannot adapt themselves at once to sudden alterations of temperature. The fact that an animal whose temperature remains for weeks at 6° or 8°C can...
raise its heat quickly to 20° or 30° C. may be accounted for by reflex stimulation, but at the same time as the respiration becomes more frequent, the increased supply of oxygen thus obtained may cause the heating; this is improbable because the blood of hibernating mammals is always of a brownish red colour, containing an abundance of free oxygen. Reflex impulses may be sent from the brain to the tissues, and more oxygen being thus withdrawn from the blood, an increase of oxidation products occurs in the blood, which added to the external stimuli may be a means of exciting the respiration, which increases until it becomes sufficiently frequent to supply enough oxygen. The temperature once beginning to rise causes further oxidation of the tissues. Corresponding to this idea, the temperature of frog's eggs slowly, then much more rapidly, when the normal temperature is reached, this rise ceases probably because other heat-regulating mechanisms come into play. The brain is the first part of the body to return to its normal temperature, followed by the other parts in order. He believes from the experiments in which he cut the spinal cord, that impulses to
heat the body spring wholly or in part from the brain, for when the cord is cut the whole process of heating is slowed, which should not be the case were there heat centres in the cord. Paroxysmal paresis is necessarily produced by such a section, but he thinks that this would not account for the slowness of heating, as the internal parts as well as the skin showed a slower rise in their heat.

All these facts point to the brain possessing a caloric centre by the influence of which upon the organs of the body, metabolism and heat production is brought about.

Rosenthal states that hibernation finds an incomplete analogy in the effects of greatly cooling ordinary mammals, as produced by dipping them in cold water, sectioning the cord or lamel
ing the skin; these animals die when their temperature is lowered to 20°, whilst hibernating animals may be cooled to nearly 0°. In both a loss of heat, a decrease of the respiration and pulse, and a sleep-like condition of the brain is produced. Hibernating animals appear to have a greater adaptability in varying their body heat than other
mammals, their nervous centres are less sen-
pitive to cold, and continue to exercise
their functions though in a lesser degree,
for a much longer time.

Unfortunately no calorimetric observations have been made.
Buffon states that during hibernation the blood is much cooled and devoid of perfume, but that nevertheless the heart continues to beat. Mangili (54) decapitated a hedgehog in May and found that its heart continued to beat for one and a half hours, slight beats of the right auricle being still visible an hour later. He examined the membrane of a bat wing under the microscope during hibernation and observed the blood slowly circulating; in the dormouse as winter sleep progressed the pulsations became less and less frequent. The heart of a warm killed in June stopped beating in 50 minutes whilst that of one killed in March went on beating for 3 hours; on cutting the large vessels near the heart, only a little blood escaped, which coagulated readily and yielded in two hours a quantity of serum.

Pallas (65) considers that the blood of animals which hibernate is at all times a little colder than that of other mammals.
Sauvy (80) remarked that by perforating an artery in a limb of a termid mammal only organs of blood birth place, and that after ligatine, no bulging of the vessel occurred; from which he concludes that the circulation is under the influence of the atmospheric temperature, and that during sleep, lethargy, it moves very slowly, but that during complete torpor the capillaries of the surface of the body are almost empty, the larger vessels nearly so and the blood stagnant; the arteries and veins of the abdominal cavity in the other hand are full and gorged with blood, and that a slight movement may be seen in hearts, subclavian, and common carotid arteries only. The heart is beating feebly and the blood is never coagulated. When withdrawn from the body the blood coagulated, it is reddish brown in colour in both arteries and veins and of the same temperature in both.

Prunelle (92) showed that in the bat the heart beats are lowered from 200 to 50–65 per minute during hibernation, and that the arterial blood is red; that in the mammal they decrease from 90 to 8 or 10.
feeble and arrhythmic beats. The circulation (91) through muscle diminished is not suspended, and the colour of the blood is violets in both arteries and veins. Berger (11) found the blood very fluid.

Marshall Hall (12) states that as hibernation deepens, the blood going to the brain becomes more and more venous, that the heart contracts for 24 hours after removal of the brain and spinal cord, that its irritability is increased; and that the left heart becomes veno-contractile, the whole blood being dark and almost devoid of oxygen.

Hunter (13) says:—Circulation goes on during hibernation, but the blood is insipid in the production of heat, owing to want of chemical change occurring either in the capillaries of the tissues or in the lungs, venous blood only is present.

Valentin (16b) found that the heart and large vessels were distended with blood, and that the left ventricle often contained blood masses. The blood was very fluid and remained so for 24 hours after withdrawal from the body of a warm-blooded by suffocation.
The average size of the red blood corpuscles in these animals is \( \frac{1}{2000} \) millimeter, and no change is visible in them during hibernation.

To determine the movements of the heart, he thrust a long needle through the chest wall into the heart, connected it with a Vibrodto phonograph, and obtained tracings from which he concludes that the heart beats two or three times, then rests for a while after which it beats again two or three times, thus resembling that of a dying animal.

After many experiments he formulated the following conclusions: — (1) Auscultation is not a certain means to ascertain the heart beat, as the animals are often to wake. (2) An exploration needle can be introduced into the apex of the heart without waking the animal or causing much irritation. (3) The duration of the heart beat is greater during winter sleep than in the waking condition. (4) The systolic part of the beat is shorter than the diastolic part. (5) Diastolic beats are rare. (6) Heart beats may be absent for several minutes in deepest sleep, or may have been present but
to pluck to move the needle. (2) Heart may be stopped by stimulation of the vagus. (3) Heart, heart, heart, and respiratory movements show no mental dependency.

He also made many experiments to ascertain the blood pressure during inspiration and found it to be about 72 millimeters of mercury in the common artery.

By examining the movement under the microscope, he studied the rate of flow and found it to be, in a capillary vessel of 0.5 mm. diameter, one millimeter every 2.72 seconds, in small veins, one millimeter every 10 to 25 seconds. This rate however varies considerably with the activity of the heart.

Hofrichter (1802) states that the heart goes on beating though the blood is cooled to 40°C by cooling water and that some regulation of the circulation still persists at the ends of the feet and now flushed with blood.

Cuvier 22 maintains that the aperture of the heart is very long, lasting two or three seconds. If the blood be says that the white corpuscles are very scarce, but never quite wanting, thus differing from Valentin.
He found that fresh blood taken from the heart showed 8.5% haemoglobin, that is 64% of the normal quantity; and that with Fina's haemocytometer the red corpuscles numbered 3.5 million or 70% of the normal. The corpuscles are of normal form but vary much in size, and the blood contains some small yellow droplets.
Nutrition.

Generalities.

Aristotle states that in Greece dormice do not eat during the whole winter, but nevertheless become very fat, sleep nourishing them more than food does other animals. Buffon pointed out that the great Greek writer was mistaken, and says that they become very fat in Autumn, that this fat is consumed during hibernation, and moreover that should they wake up they eat the food with which their holes are stored. Bats however pass the entire winter without food as do also marmots which become very fat in Autumn but emerge from their holes in Spring in a lean condition. They void neither urine nor feces, and live almost wholly by transpiration.

Mangelli (50a) also observed that dormice wake up from winter-sleep at rare intervals and eat. By weighing marmots at regular intervals he ascertained that they lost weight during hibernation, and that this loss was greater in animals which were often disturbed, than in those which were allowed to remain at rest, and he concludes
that the fat of these animals is of great service to them as it acts as an internal food on which they subsist during interminable intervals in their sleep.

Pinnell (9a) noticed the great thickness of the subcutaneous and abdominal fatty tissue in all animals at the commencement of hibernation and pretends that the fat or subcutaneous matter by penetrating the skin, produces a varnish on its outer surface which effectively prevents loss by "transpiration", the other secretions are not arrested though much diminished and evaporation little or none. By weighing he ascertained that all hibernating animals lose weight during hibernation especially warmbears.

Edwards (10) says no food is taken for several months Marshall Hall (11) however observed that the hedgehog ate all intestals but passed no urine or feces. Barker (12) states that during hibernation the body weight does not decrease but either remains the same or even increases, his experiments were performed on cold-blooded animals. Sacc., in Regniart (13-14) and Reisch (15-16) was the first to show clearly that the animal frequently becomes heavier or maintains for a time its body weight.

Valentini (16a) states that hedgehogs eat at in-
tervals during hibernation, and that the marmot, which is fat in Autumn, loses weight gradually. He made elaborate weighings in marmots and hedgehogs extending over a period of 6 or 7 years, and states that though there is a general decrease yet the amount lost from day to day varies somewhat and sometimes the body weight increases slightly; the animals were kept in an ordinary atmosphere, the quantity of water vapour in which varied continually, the hypsographic nature of the hair and feathers may easily account for any slight increase in the body weight. He also made similar experiments on animals kept in a dry and a moist atmosphere, and gives charts setting forth his results. Marmots lose 1/4 to 1/3 of their total weight during hibernation and hedgehogs about 1/4. The loss is caused by perspiration, urination and defecation; it is least during very deep sleep, greatest during the intermittent periods of waking.

He also weighed the various organs individually and found that the brain, spinal cord, eye, salivary glands, oesophagus, parts of the small and large intestines, kidneys and bladder hardly lost weight at all; whilst the fat and the hibernating
gland last relatively most, the latter 7/10 of its original weight; it is only used when the animal is awake, not during sleep. Muscle and liver also lost much weight, but not so much as one would expect. The skeleton also loses a little.

The average loss in the mouse in per kilo of body weight per hour was found to be in light sleep, 0.065 gram; in deeper sleep, 0.021 gram, and in deepest sleep 0.014 gram.

Hrdal (186) states that zeigels wake up and eat; Bernfield (23) found that the animals voided excrements and urine; Besant (24) that the tone metabolism varies with the temperature and Dukin (28A) that the urine is constantly secreted by the kidney as can be seen by making a potato opening.

**Alimentary Canal.**

Mangili (5a) examined a marmot killed in May after it had wakened, and another in March which was still hibernating. He found the stomach in both animals small and quite empty, the intestines empty, and in the cecum and rectum only a minimum of fecal matter.

Somelé (9a) found, in a similar animal, the
stomach small, folded on itself and wrinkled, containing a thick white liquid of mucinous and adhesive nature; also seen in the small intestine which was otherwise empty and of small size. Bargers (11) found only a few food remnants in the stomach and nothing in the intestines.

Marshall Hall (12) found the digestion unaffected in the hedgehog but Hunter says that this animal with a temperature of 30° F. has no desire for food and its stomach no power of digesting it.

Valentine (16) who examined the mammoth found that the mouth, pharynx and esophagus showed no peculiarities at any time. At the beginning of hibernation the stomach was big, round and contained a light watery acid fluid in which were flocculi, the superficial part of the mucous membrane was acid, the deeper parts neutral in reaction. After six weeks pleft the stomach contained a yellow, viscid, neutral, or slightly acid fluid, in which fragments of epithelium could be seen; the mucous membrane was neutral in reaction. After two or three months the stomach was rounded small and contracted, containing much strongly acid fluid with flocculi and the mucous membrane very acid. At the end of
hibernation, the contracted stomach contained no fluid at all.
These observations seem to indicate that a watery fluid is excreted in the stomach during the first half of hibernation which disappears later on.
In the first animal, the duodenum, which was alkaline, contained only a little mucus, the jejunum and ileum were alkaline and empty. The cecum contained a tough yellowish mass, and the colon only a little fecal matter near the sigmoid flexure. In the second animal, the duodenum contained much yellowish or greyish mucus mixed with epithelial debris, the jejunum and ileum were much injected and contained a little mucus, the cecum full of greenish brown matter. In the third the duodenum was alkaline with blood-stained mucus in it, the jejunum and ileum almost empty, there being only a little alkaline bile-stained mucus in the lower part, the cecum which was neutral in reaction contained a large quantity of a neutral brown material, in the colon which was faintly alkaline there was a little mucus, and in the rectum a large number of separate alkaline fecal masses.
This author then gives accurate measurements
of all the parts and pretends that the intestines diminish in length during hibernation. With regard to digestion he states that during hibernation most of the parts examined showed no activity; starch was not transformed into sugar in the mouth or stomach; boiled egg albumin was not affected either in the stomach or intestine by extract of chopped pancreas; however, cooked starch into sugar, but only very feebly, and no pancreatic juice passes into the intestine. The stomach on the addition of hydrochloric acid was found capable of digesting proteins. The further made many experiments by placing food in the mouth and sections, with but little result.

Hrvalle (81) states that the gastric juice will digest fibrin at a temperature of 0°C. With that the intestinal canal is 0.2% of the bodily weight, and Bönner (82) that the stomach is nearly empty, only a small quantity of watery acid mucus fluid being present, and that the intestines show no peristaltic movements either spontaneous or on being irritated, though the muscle fibres contract locally at the point of stimulation.
Liver and Bile.

Saying (84) investigated the bile at various seasons of the year but found that it did not vary in composition to any appreciable extent. He states that the bile is pale green in colour, syrupy in consistence, bland and hardly at all bitter to the taste, rich in albumin, poor in gelatin and very watery; no doubt it contains sugar.

Valentine (166) says the liver of the marmot bears all times of the year a beautiful brown colour with well marked lobules. Its size diminishes much during hibernation, the individual cells becoming smaller and full of fat like bodies of varying size.

The gall bladder is always quite full of dark greenish bile, neutral or nearly alkaline in reaction, containing small coloured granules and debris of various kinds, but no cholesterol.

When boiled or tested with Fehling's solution it gives no reaction, it is turned blue-green with hydrochloric acid, and a play of colours is obtained on adding nitric acid to it.

When evaporated to dryness it gives a residue equal to about 20% of its total weight, which when extracted with cold ether yields a green fluid from which greenish glistening crystals.
are obtained on evaporation. An alcoholic extract shows no polarity.
With regard to glycogen he states that the liver, extracted, with cold and then with hot water, reduces Fehling's solution powerfully. 5.4 grams of fresh liver contained 2.87% of sugar when titrated with Fehling's solution. Blood from the liver treated in the same way yielded 0.82% of sugar whilst blood taken from the heart of the same animal yielded none.

Bennard says that rabbits and guinea pigs, while they are starved, have no glycogen in their livers, this is confirmed by Valentini in the case of both marmots and hedgehogs, but he found that in marmots the opposite obtained. Glycogen is present in the livers of the marmot during the whole period of normal hibernation, this glycogen is more stable than that of ordinary mammals.

Von (20) says the liver is equal to 20% of the total body weight; the amount of water which it contains is diminished during hibernation. When tested for glycogen it is found at all times to contain about 2.22%, whilst the muscles contain 0.371%. The glycogen is formed during
fasting, but again and again destroyed in the
waking condition.

Diirich's (22) found the gall bladder distended in
all animals killed by him during winter sleep.
The bile examined for iron by Funckes' method
gave negative results.

The capillaries of the liver contain white blood-
corpuscles with iron holding granules of variable
size in variable quantities; they are very numerous
in old animals; the liver cells show micro-chemi-
ically no iron reaction. He concludes that
there is a great breaking down of red blood-
corpuscles during hibernation in the liver, spleen,
and red marrow; and that the iron accumulated
in these organs is applied to the new formation
of red corpuscles on the resumption of hibernation.

Valentini (16) is the only author who has ex-
amined the feces passed during hibernation.
He states that they are entirely composed of
excretions without any admixture of food
remnants; they consist of altered bile, a bile
pigment, coloherin, in small quantity, probably
also some derived albumin, about 6.45% of
nitrogen, basic lime phosphates in large,
and alkaline sulphates in small quantity. Chlorides are absent which is remarkable.

Kidney, Bladder and Urine.

Mangeli (5a) that the bladder was always distended and filled with clear urine in all animals killed by blunt during hibernation. Valentin (16a) states that the kidney undergoes no change during winter sleep, it is not contracted, filled with fat, pigment granules or crystals as stated by Stannius in the case of the frog. Secretion of urine through in limited quantity occurs during hibernation, it is acid and contains crystals of triple phosphates. The urine of waking hibernators is often alkaline.

The urine (16a) is brownish yellow in colour or greenish by reflected light at the commencement of hibernation, in the spring it is transparent, pale yellow and possesses a musky-like odour. Freshly passed urine being acid contains no triple phosphates and has a low specific gravity about 1.027. It contains carbon dioxide between 0.15% and 0.60% phosphoric acid, and between 0.34% and 1.02% sulphuric acid, these two acids do not vary in parallel
Common salt also in very small quantity 0.04% to 0.30%, urea 3.32% to 6.17% varying with the depth of sleep. The urine when boiled gives a precipitate of albumen, but the ingestion is not reduced by it; bile pigments are only occasionally present; the ash contains much lime, 0.13%, and magnesium salts.

At each act of micturition 49.4 grams of urine are passed, which gives a daily average of 0.959 gram per kilo of body weight. Urea forms 79% of the solid residue after evaporation, but varies much in quantity; this represents 0.026 to 0.163 gram per kilo of body weight per diem.

Hodatt (184) states that the urine which is being continually excreted by hibernating insects is always alkaline. Genet (182) found the bladder distended with a boronite, palegreen, slightly acid urine which with Taffe's test showed traces of albumen but no uric acid; an abundance of urate is indicated by the same test.

According to Dubois the urine passed during hibernation is always less dense than that passed in summer. A certain quantity of water and the condensive principles of Browncoat are reabsorbed owing to the long sojourn of the urine in the bladder.
Fab.

Most of the foregoing authors have mentioned the great accumulation of fat that takes place in these animals during autumn. Savigny (80) found the fat of marmots white, soft and of texture like that of the fig, whilst that of hedgehogs was greenish in colour. The fat had neither smell nor taste and did not solidity in the animal's body during hibernation.

Conta mentioned by Valenti (166) maintains that the fat of marmots is red during winter sleep though white in summer, but this Valenti denies, as also the statement of Prunelle, that the fat varnishes the skin.

**Hibernating Gland.**

Cuvier (35) was the first to mention the existence of the hibernating gland. Prunelle (92) gives fullity its anatomical relations in the marmot and states that it is continuous with the thymus gland, that it is only represented in summer by a few reddish threads, but becomes very big in autumn to disappear gradually during the winter sleep, and that it is supplied by many blood venules derived from the intercostals and inferior thyroid, which cross it in all directions.

Marshall Hall (12) however denies that it has any-
to do with the stygnum, maintaining that
it is just a mass of fat.

Vulpes (163) gives with much detail the position
of its Venous Pits in the marmot, and says
that the lobules contain numerous aggregations
of granules which resemble the stygnum in structure,
and which are unaffected by acetic acid.

Hornblower (181) says that it is believed to be present
in all hibernating mammals, that it is looked
upon by some as a part of the stygnum gland,
and by others as a special function of the
hiding place of the stygnum:

It is very large in the geigel, less so in the hedge-
hog and hamster; it is interspersed with all the
large vessels coming from the heart and sends
out processes along the sides of the spinal column
in the chest to the diaphragm, where it surrounds
the sympathetic nerve; other lobules of the gland
leave the heart vessels and extend into the
neck back and breast, and one lobule is
found below the pectoral muscle. The gland
is sometimes yellow, sometimes greyish, yellow
in colour; it is larger in autumn before than
in spring after hibernation.
Blood Glands.

According to Valentin (64) the spleen exhibits no important change during hibernation, though columnar, colorless crystals may be seen in the parenchyma of the gland; in one case cells which seemed to contain blood corpuscles were found in the adrenals.

Aniche (23) found the pulp cells of the spleen very rich in large von Winiwarter granules which were turned black by ammoniacal sulphide. Similar granules were observed in the red marrow of the sternum, but were absent from the fatty marrow of the long bones.

Muscles.

Voit (202) found less water in the muscles during hibernation than in summer; the amount of creatin however being the same, about 0.296%.
Muscular and Nervous Irritability. Condition during hibernation of the general and special senses.

Buffon (5) thought that dormice were almost deprived of all use of their senses during hibernation, and felt pain only when it was intense, such as that produced by a deep cut or burn. Murgile (5b) held that marmots when pricked or otherwise excited showed no signs of life, but that the muscles of hibernating hedgehogs responded to stimuli one hour after the animal had been decapitated. But when forced into wakefulness, therefore, they could not hear, but the slightest light of his torch caused some to move a little. He placed a marmot's head and neck in spirit, and it showed movements for half an hour, from which he concluded that the vital principle is greater during winter sleep than in the waking condition. Red muscles removed from the body contracted when stimulated electrically three or four hours after death, like those of cold-blooded animals. In severe cases, they ceased to respond after two hours. Saining (38) found that pricking the skin, nose, and
feet with a knife caused lethargic hedgehogs to move a little, dormice and bats to move more, and that their movements were more pronounced with electrical stimuli. Marmots showed no movements with any of these. He concludes that irritability is diminished in proportion to the depth of the sleep. Prussell (9a) stimulated a torpid marmot with electricity but found it required a powerful stimulus to wake it; he cut into and ligatured vessels in marmots without their showing any signs of feeling, and concluded that sensibility is much diminished, as is also irritability, without however being entirely lost.

According to Marshall Hall (12), in the case of the hedgehog the muscle fibre of the heart becomes more irritable, and a touch of the skin is at once resented by the animal; the muscles of the trunk remain irritable for a long time after decapitation; general sensibility is not impaired, though sensorial functions are almost suspended. Muscular irritability is unimpaired, there being no stiffness of the muscles.

Valentini (6b) ascertained that when a marmot
is well asleep, operations may be performed such as ligature of vessels, dissection of nerves without exciting any movement on the part of the animal; a bright light thrown into the eye and a piston discharged close to the ear produce no result; Carustie ammonia applied to the skin ultimately makes it, some mechanical stimuli have more effect. He also pointed out (161) that ciliary movement persists longer than in primates; the cilia continuing to move for 2 to 4 or even 6 days after death in the nasal and buccal cavities, the muscles remain longer irritable, 6 to 8 hours or even 12 hours and nerve remanis excitable from one to five days after death.

Horvath (180) found that nerve and muscle in evicted geizels retain their irritability, slight electrical stimulation being sufficient to cause contraction, the skin muscles are also excitable. In the hibernating mouse the Quincke (183) found a want of great reaction to external stimuli. Spontaneous movement and reaction to stimuli were often less with a body temperature of 25° than with one of 18°. The reflexes remain at work however as is shown by the fact that
distention of the bladder and rectum produce waking. The centre for these reflexes must be in the brain because if the cord be cut they cease below the point of section. The reflexes of the hind foot are in every respect similar to those of waking animals, and lasts for 20 minutes after death; reflex and voluntary contraction is very slow in sleeping mammals but persists 6 hours after death. 

Rosenthal (64) demonstrated the greater vitality of the tissues of hibernating animals as compared with other mammals, so that they closely resemble in this respect cold-blooded animals.

The dormice kept by Florel (66) showed on being irritated reflex movements and emitted slight cries.

According to Dubois (68a) external stimuli produce reflex movements and the external reflexes are in their normal state of activity.

End of the Literature.
Original Observations.
Physiology.

Introduction.

Although the literature regarding hibernation is very voluminous, little definite general knowledge has been obtained, owing to the number of different kinds of hibernating animals used by the various authors in their studies. Now each species of animal possesses many idiosyncrasies which modify the phenomena of winter-sleep in no inconsiderable degree, and as Horvath (1861) has justly remarked, the literature only makes the subject more difficult, as it only contains a few facts which are disputed, requiring renewed investigation, and to get a thorough insight into the subject many forms as yet uninvestigated must be taken and thoroughly worked out.

The intensity of winter-sleep, its duration, and the phenomena accompanying its resolution vary very, very
Considerably from one animal to another such animals as the marmot and geel being profound hibernators, their awaking is correspondingly slow; whilst the bat, dormouse and hedgehog are such light sleepers, that very slight alterations in the external conditions are sufficient to arouse them; this is especially the case with the dormouse which is hardly a hibernator at all.

I have inserted a list of the better known hibernating animals which occur in different parts of the world with their habitat.

Mouse coloured bat (Despertilio murinus) Great Britain

There are 15 kinds of British bats, all of which hibernate.

Hedgehog (Erinaceus europaeus) Plains Great Britain

Scree (Ctenetes scandatus) Plains Madagascar

A considerable number of animals closely allied to these also hibernate.

Dormouse (Muscardinus avellanarius) Plains Great Britain

Fat dormouse (Myopus glis) Plains Europe

Garden dormouse (Myopus quercinus) Plains Europe

Marmot (Arctomys marmotta) High mountains Europe
Bobac (Anas platyrhynchos) Plains, Siberia.
Hare (Lepus timidus) Plains, North Georgia.
Raccoon (Procyon lotor) Steppes, Russia.
Potto (Perodicticus potto) North America.

There are many other North American species that hibernate.

All these animals belong to the two classes, Insectivora and Rodentia; there seems to be no authenticated cases of Carnivora hibernating, though several bears are paid to do so.

From this list it becomes apparent that though many kinds of animals indigenous to the British Isles are subject to hibernation, none are deep sleepers, and most of them too small to be of much use in physiological research. The hedgehog is the only animal of any price, and is the most easily procurable, though owing to its shy nature is eminently unfitted for handling, putting the investigator in this country in an unfavourable position for undertaking any investigation into the phenomena of hibernation; again if animals be imported from

W. Africa.
other lands, their domesticated condition militates against investigation, owing to the fact, that when tamed they refuse entirely to hibernate or do so only very imperfectly, which is especially conspicuous in the case of the marmot.

I have confined my attentions entirely to the hedgehog, but from its very nature have been unable to enter into any investigations concerning respiration, body temperature, heart beat etc. These points have however been so fully investigated already by continental observers that very little remains to be done with regard to them, with the exception perhaps of Calorimetricial measurements of the body heat. Only the marmot and zeigel would be portable for such experiments, as the body temperature at once begins to rise as soon as the animal makes any movement. The hedgehog cannot be touched without at once resenting the interference by two or three deep inspiratory movements ac-
Compared by an angry grunting sound.

Variation in body weight has also been so fully studied in various animals by Valentini, notably in the marmot and hedgehog, that nothing remains to be done in this direction either; and even were one to undertake such a research it could not be done in this country without elaborate precautions, owing to the constantly changing hygrometric state of the atmosphere, which in the case of an animal furnished with such hygroscopic dermal appendages as the hedgehog would not be very reliable, owing to the extremely slight daily diminution which the body weight experiences. My observations have therefore been mainly confined to the blood, bile, urine and feces. These have hitherto attracted less attention than one would have expected, possibly owing to the defective state of organic chemical knowledge in earlier times; and further, changes which occur in the general tissues of the body during or
subsequent to hibernation have been almost neglected.

I propose therefore to take the tissues up in detail, beginning with the alimentary canal and its glands, then passing to the blood vascular system, and lastly taking up such other less important parts of the organism as time shall permit. At the very outset I was met by a difficulty, in that no definite account of the normal appearances of the tissues in this animal could be found, and was therefore compelled to work out the normal histology of the tissues and organs of the body before being in a position to state what changes might be present in them during winter sleep. I have entered with some detail into the normal histology of the parts, laying special stress on any peculiarities which they may exhibit, and at the end of the description of each part pointed out what changes I have observed incident to the lethargic condition. In this way I hope to
throw some further light on the subject of hibernation.

The Blood.

Colour.

The blood of hibernating hedgehogs varies somewhat in colour, being of a dark though not Venus red in the arteries during profound sleep, and much brighter in those in those animals whose sleep is less intense. At all times when examined spectroscopically it gives a very decided oxyhemoglobin spectrum proving conclusively that there is no deficiency of oxygen in the blood as some writers have maintained.

Quantity of the blood.

The blood of a healthy animal weighing 570 grams killed in July and fully bled from the heart weighed 89.53 grams, the blood was fluid and of a bright red colour and clotted in some 5 to
7 minutes. The percentage of haemoglobin contained in it as estimated
by Grey's haemoglobinometer was found to be 85%.

The blood of another healthy animal weighing 617 grams, which was killed
in March towards the end of winter sleep, clotted as before and weighed only
14.5 grams though the limbs were pressed and every attempt made to
fully empty it of blood. The blood was somewhat thick, flowed less readily
than in summer, was of a darker color, but clotted with as great readiness and
showed the same percentage of haemoglobin as that collected in July. After
standing for some time, the clot did not contract and no serum was ob-
tained, though in the case of the former animal it was abundant and of a
pale straw color.

This may be taken as a type of what obtains in all animals killed during
hibernation. Once and only once did I obtain sufficient serum for investi-
tion from the blood of an animal killed in March, the coagulated blood being kept under a bell jar in which were pieces of blotting paper soaked in water, this precaution was necessary and in all cases resorted to, to prevent loss of persim by evaporation.

Table setting forth the above results.

<table>
<thead>
<tr>
<th>Season of Year</th>
<th>Body-weight in grammes</th>
<th>Weight of Blood in grammes</th>
<th>% of Blood to Body-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>570</td>
<td>29.53</td>
<td>5.18%</td>
</tr>
<tr>
<td>March</td>
<td>617</td>
<td>14.5</td>
<td>2.35%</td>
</tr>
</tbody>
</table>

By glancing at the above table we see that the quantity of blood is greatly diminished towards the end of hibernation, for the heavier animal gave the least blood, its percentage also when compared with the body weight is considerably less being only 2.3% which is barely half that shown by the blood in the case of the July animal.

This loss of weight is probably in great measure due to the abstraction of water from the blood and tissues
generally by the kidneys, water which is voided in the urine and thus lost to the organism, and is not replaced as the animal, throughout the whole winter, neither ate nor drank, though it poached now and again to void its excreta, but I purposely kept it without food or water as not to interrupt the even tenure of the changes brought about by the long fast natural to hibernation.

The clot

The clot produced by such blood is dense, very firm and of a dark color except at the surface where it has been in contact with the air and absorbed much oxygen, it is then scarlet.

The Serum.

The serum which I obtained from one animal killed in March as above detailed was clear and of a pale straw color. I examined it chemically for albumin and its allies, and found that when added to tap water a slight
precipitate occurred, when added to a saturated solution of magnesium sulphate heated to boiling, a heavy precipitate of globulins occurred (this is Hoycraft's test). When carbonic acid was passed through it for half an hour a thick precipitate was the result, which also consisted of globulins. This filtered two or three times till a clear fluid was obtained. Yielded when nitric acid was added to it a dense precipitate of albumin.

Another portion of serum shaken with magnesium sulphate to saturation for half an hour and filtered, thereby eliminating all the globulins, gave on addition of nitric acid carefully down the side of the test tube, a distinct ring of coagulum at the junction of the two fluids, demonstrating the presence of albumin.

From the above tests it will be seen that the blood serum of a hedgehog, that has passed the greater part of the winter in the hibernating condition
contains abundance of both serum albumin and serum globulin. This differs from what one would have expected, as in fasting animals there is a diminution of serum albumin occurring in the blood. (Mackendrick)\(^{(32)}\)

**Reaction of the blood.**

No experimenter seems hitherto to have examined the reaction of the blood during hibernation. I procured a series of test papers prepared for the quantitative determination of the alkalinity of the blood as directed by Waycross. These papers are highly glazed litmus papers of definite strength, the glaze prevents any staining of the paper by the colouring matter of the blood, and by being nicely graduated permit its alkalinity being estimated from the tiniest drop. All that is necessary is to catch the drop of blood on the paper, allow it to remain there for 10 seconds, wash it off with distilled water and blot with neutral blotting paper, when any alteration of the red tint can be
at once seen.

I proceeded in this careful way, obtaining blood by puncturing any exposed part of the animal such as the nose or foot and obtained the following results:

<table>
<thead>
<tr>
<th>Date</th>
<th>Strength of Paper</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 11th</td>
<td>( \frac{w}{100} )</td>
<td>Not affected.</td>
</tr>
<tr>
<td></td>
<td>( \frac{w}{200} )</td>
<td>Fairly blue.</td>
</tr>
<tr>
<td>19th</td>
<td>( \frac{w}{320} )</td>
<td>Doubtful</td>
</tr>
<tr>
<td></td>
<td>( \frac{w}{450} )</td>
<td>Distant blue.</td>
</tr>
<tr>
<td>Dec. 10th</td>
<td>( \frac{w}{450} )</td>
<td>Faint blue.</td>
</tr>
<tr>
<td>March 10th</td>
<td>( \frac{w}{450} )</td>
<td>Very faint blue.</td>
</tr>
</tbody>
</table>

Other animals tested in like manner gave similar results.

From this it will be seen that the alkalinity of the blood diminishes progressively during the hibernating period, which taken with the fact that the urine progressively becomes more acid is highly interesting.

The phosphoric acid produced in the metabolism of the organism requires to be eliminated by the kidney, and
is so thrown out in the form of acid salts, which in part cause the acid reaction of the urine, as fermentation goes on the phæne alkali of the body yet gradually used up to produce these acid phosphates and as the animal is taking no food whereby a fresh supply of alkali could be introduced into the blood, this great medium of interchange between the tissues becomes more and more destitute of alkali, as also all the tissues of the body generally. The urine on the other hand becomes more and more acid thus expressing the dearth of alkali in the organism.

**Number of Blood Corpuscles.**

Estimated in the usual way by means of Thoma's haemocytometer as supplied by Zeiss of Jena. The blood was obtained by incising the foot of the animals, as a penile puncture did not always produce a sufficient flow of blood for the purpose. For this it was necessary to administer chloro-
from to the animals as their reflexes are so acute that on the slightest touch the muscles reflexly contract and nothing remains but a spring ball from which no blood can be obtained. Just enough chloroform was therefore given to overcome the muscle reflexes and permit of a foot being seized and blood obtained from it.

I made many countings on various individuals and found that even in persons the number of corpuscles varies somewhat. In all cases I counted ten large pyramidal of the instrument, and in some cases made many countings, taking the average; in this way I hoped to arrive at fairly accurate results, unfortunately the record is complete in the case of one animal only, the others having all either been killed for their times or having died during winter sleep from too frequent disturbance.

The average amount in summer from ten countings in one animal, a fine healthy male which we will call A, was found to
be as high as 10,260,000 red corpuscles, and 18,000 white. In another animal also a fine male, say B, the average of ten countings was 10,289,000 red and 31,000 white; in yet another, a male also but of smaller size and younger, C, there were 8,586,000 red and 17,000 white.

The red corpuscles are very small, 5μ in diameter but very numerous, the white ones are large 6 to 7μ and profusely few.

On July 9th, 1840 the number of corpuscles in C performed to be red 8,700,000 and 8,840,000 giving an average of 8,820,000 with 21,000 white.

On July 14th, 1840 the same animal C had 9,280,000 red and 14,000 white.

Oct 21st, 1840 Animal A which was not hibernating and whose blood was scarlet, showed 11,355,000 red and only 3,166 white. On the same date C had begun to hibernate but was very easily roused and had scarlet blood showed 9,320,000 red and 5,714 white.

On November 11th, 1840 animal C had just
awakened, but its blood was red, not purple, in examination 11,800,000 red and 7,600 white corpuscles were found.

November 19th 1890. It was very ill, had scarcely hibernated at all, and whose blood though very dark gave the oxyhaemoglobin spectrum furnished 10,100,000 red and 11,600 white corpuscles. It died in a few days from asplenic pneumonia affection, as shown by the post-mortem examination.

On December 10th 1890. C was hibernating but had red blood; the number of red corpuscles was 12,760,000 that of the white 7,428.

On March 5th 1891 C was hibernating quietly, blood red, corpuscles: red 11,620,000 white 11,330.

On March 27th 1891 C still hibernating blood red, animal passed a little uric when under chloroform. Red corpuscles 10,410,000, white not counted.

Many of the red blood corpuscles were distended, and evidently breaking down.
By comparing the figures in this table we see that the red blood corpuscles increase in numbers as the hibernating period approaches, so that the animal when it falls asleep may have the maximum number of oxygen carrying units. The number of red corpuscles apparently goes on increasing during the first half of hibernation which is contrary to what Snider (23) found in the mouse. But as we have already seen the blood rapidly becomes concentrated, especially at first, by the withdrawal of water from it, to supply the fluid part of the
urine, which is voided at fairly frequent intervals at first, but at less and less frequently recurrent periods in the later stages of hibernation. Further we have seen that the total blood in the animal becomes greatly diminished as hibernation goes on; therefore the increase above noted may only be apparent owing to concentration of the blood, the corpuscles may remain the same in number or may even be diminished in quantity gradually, as stated by Bierl(23), and this is further borne out by the last figures which show a fall in their numbers, whereas did they remain the same, the further concentration of the blood brought about by the production of urine would make their number appear to increase; it is therefore highly probable that during the whole period of hibernation a certain destruction of red blood corpuscles is continually going on, which loss is not replaced by a corresponding production of young cells, though
some are probably produced; and further, as will be seen when dealing with the histology of the blood, the red corpuscles diminish in size as hibernation goes on, many very small ones, 1 to 3 μ in diameter, occurring towards the end, those of ordinary size becoming fewer and fewer.

During summer when the animal is enjoying abundance of food and water, the loss occasioned by the urine is replaced rapidly and we get no concentration of the blood; the augmentation in number here is probably a provision produced with the intention of counteracting to a certain extent, the loss which will inevitably take place during winter sleep.

With regard to the white corpuscles an evident rapid diminution occurs at the very commencement of hibernation; they wander out of the blood stream and are found in large numbers in the submucous coat of the intestines and in other places, as will
be shown when these tissues are dead with; what causes them to augment progressively as seen in the table; as hibernation goes on would be difficult to say, perhaps a certain number pass back again, or the activity of the blood forming glands which never quite cease to produce leucocytes may be sufficient to renew the white corpuscles after their migration has sensibly diminished or come to an end.
Bile is being continually excreted by the liver during the whole period of hibernation, though probably only in small amount; often the animals at what period you may, the gall bladder is always found distended with a clear, lumpy, very mobile, intense prussian green coloured bile.

In a hedgehog which weighed 670 gms, killed in March, 8.75 gms. of bile was found in the gall bladder, it presented the characters given above, and was alkaline in reaction. On addition of acetic acid a precipitate of mucin occurred, though not very abundant. Treated with cold permanganate and the usual play of colour was obtained beginning with the green, bili verdin could also be clearly demonstrated by the use of the spectroscope. Bile placed in a small test-tube, carefully closed with cotton wool, and placed in the dark retained its colour for several...
weeks, but by the end of two months it was pale olive green in colour, decomposed and a white flocculent precipitate had fallen to the bottom of the tube.

In the addition of sugar and sulphuric acid to the fresh bile a cherry red colour became visible, indicating the presence of bile acids. When tested for protein by the Prussie iodo test a precipitate was obtained as also with Weil's reagent and with cold nitric acid.

The passage of a stream of carbonic acid through it caused a precipitate of globulin, the fluid was then filtered, and the various tests for albumen above mentioned again applied to the clear filtrate with the result that no precipitation occurred, proving that no albumen was present in the bile.

This was confirmed by shaking the bile with magnesia sulphate saturation and filtering, when on applying the above mentioned tests for proteins to the clear filtrate no precipitation occurred.
The presence of chlorides was ascertained by the addition of nitrate of silver, which produced an abundant precipitate; that of phosphates by precipitating them with ammonium acetate; and sulphates were demonstrated by being precipitated with chloride of barium.

There was no trace of reduction of ferrie's solution when heated to boiling with the bile showing the absence of sugar.

The bile of another animal killed about the same date presented exactly the same characters, with the difference, that sulphates were present in only very small quantities.

A small animal, which was killed and partly devoured by the larger carnivores in October, soon after its arrival by train, was found to possess a reddish green bile, indicating the presence of some bilirubin, mixed with the biliverdin. When tested it was found to present character identical with that of animals killed
in March, and given above.

Also the bile of that animal which died of pneumonia, and which remained in the body a day or two after the animal was dead exhibited a decided redish green colour, indicating clearly the presence of bilirubin. On being subjected to the above-mentioned tests it gave results identical with those already detailed, and which do not differ from those obtained from the bile of animals killed in July.

From the above we may conclude that the bile of hibernating hedgehogs does not differ materially from that excreted during summer except in quantity, and perhaps occasionally in the amount of phosphates and undisolved uric acid, as pointed out by Valentin (16) in contradiction to the statements of Sainsy (32). Uric acid is ever present.

The intense green colour of the bile of this animal, which though omnivorous in its habits, prefers wormwood,
insects, and other forms of carnivorous diet, is remarkable, lending as it does to uphold the writings of those modern investigators who hold that the formation of bili-subrin in the bile of man is, as I have shown to be the case in this animal, due to a large extent to post-mortem reduction.
The Feces.

When the animal makes as it does at longer or shorter intervals to micturate and to defecate it passes two or three well formed, smooth, oblong, dark green fecal masses which soon harden and assume an almost green black colour. If one of these masses be dissolved in a little distilled water, a greenish solution is obtained, but the whole mass does not dissolve. The solution treated with pure nitric acid gives the play of colours characteristic of bile pigments, and the fluid possesses an odour which recalls in a faint way that of the fresh bile itself. When phleumum with pyreth or the addition of sulphuric acid, no green colour is obtained in the foot or in the fluid itself, marking the absence of bile acids. Willim's reagent and other tests for pyreth have no reaction on the solution.
Nitrate of silver remains without effect when added to it, even after acidulation with either acetic or nitric acid.

Both molybdate of ammonia and acetate of uranium when added give precipitates characteristic of phosphates.

Barium chloride also gives a precipitate indicating the presence of sulphates.

If a foetal mass be treated either with either or but absolute alcohol no cholesterinic is obtained from it, as on cooling and evaporating the alcoholic or ethereal extract no crystals characteristic of that substance are obtained.

When dissolved in a weak solution of caustic potash in water a somewhat gelatinous fluid is obtained, which on the addition of commercial alcohol gives an abundant precipitate of mucin.

From the above tests we see that the forces passed during hibernation consist of mucin to which certain parts of the bile have been added; no particles of food remain in the alimentary canal and therefore none appear
in the dejections.

The bile acids which contain sulphur are doubtless split up in the intestine into their component parts; the sulphur among other things being reabsorbed into the organism to prevent undue waste, some part of the bile acids no doubt find their way into the feces but not as such; simpler compounds being substituted for the complex bile salts. It is also a significant fact that chlorets and especially ammonium salt, which is of such great service to the organism, should not be present in the dejecta, having been all reabsorbed from the bile during its passage in the intestine. Sulphates which are sometimes found in only very small quantities in the bile, are however present in fair amount in the feces.
The Urine.

Even during activity the hedgehog does not appear to void its urine every day, for in summer though a vessel was always carefully placed under the cage in which they were, cage which possessed a perforated bottom leading into a funnel, urine was not always found in it at the end of 24 hours.

Each animal passes on an average from 15- to 20 cubic centimeters of urine in the twenty four hours in summer. This urine, which is faintly acid or neutral in reaction, slightly turbid in appearance and yellow in colour, deposits on cooling a large quantity of colourless crystals, which are soluble in any mineral acid, such as hydrochloric, nitric, etc. They are probably phosphatic in nature and exhibit various shapes as well be seen from the figure on Plate xii, which was drawn with a camera.
luced from a preparation of urine passed on July 17th, 1890.

I examined the urine at frequent intervals during nearly a whole year, with varying results, of these I now give some examples.

July 2nd 1890.

15½ C.C. urine passed during the preceding twenty-four hours. Urine slightly acid in reaction, turbid, yellow in colour, and presenting a heavy flocculent, greyish-white precipitate at the bottom of the flask. When examined microscopically the precipitate exhibited colorless crystals, similar to those shown in fig. 78. Pl. XL. and also some amniocular ones like those of calcium phosphate in appearance, though not grouped in stars. They were all soluble in hydrochloric acid. Starch grains, debris of vegetable matter and bacteria were present.

On addition of uranium acetate to the urine, a precipitate of phosphate of uranium was obtained; in like man-
sulphates

new precipitates of phosphate and chlorides were obtained in abundance.
on the addition of barium chloride and nitrate of silver solution respectively.
on the addition of a few drops of nitric
acid a solidification took place
owing to the production of undissolved
area crystals, showing that the urine
must have been very concentrated,
no doubt owing to some loss of fluid
by evaporation. For this reason
the quantitative estimation of the
area may be over looked as it is
pure to be fallacious.
on applying the mercuric test a trace
of purple colour was obtained, indic-
ating the presence of uric acid.
jaffe's test for indican was without
result as were tests applied to deter-
mine whether any albumin or puriwas
present.

July 4th 1840.

Urine from 10 to 15 C.C. cloudy
and full of precipitate, performers, pow-
dering somewhat like mili just taken.
from the cow and still warm. The reaction was acid. The same tests were applied to it as in the above case with similar results.

A quantitative estimation of urea was made by Hüfner's method as follows:

5 c.c. of urine carefully measured were placed in a little burette and lowered into the conical flask which contained about 15 c.c. of freshly prepared hypobromite of soda and the test proceeded with in the usual manner. 36.173 c.c. of nitrogen were found to have been produced after sufficient time had been given for the gas to become cooled to the temperature of the room, which was 16.5 °C and the atmospheric pressure 29.55 inches of mercury.

In this and all other estimations of urea by this method I have reduced the volumes of gas obtained to the temperature of 0°C. and normal pressure so that the results obtained at different times of the year might be strictly comparable inter se.
For this purpose we have the formula:

\[ V_0 = V \times \frac{h'}{h} \times \frac{1}{1 + at} \]

in which

- \( V_0 \) = volume of gas at 30 inches of mercury and 0°C.
- \( V \) = the volume at the temperature of pressure at the time.
- \( h' \) = the pressure at the time of observation.
- \( h \) = the normal pressure.
- \( t \) = the temperature at the time of observation.
- \( a \) = a constant 0.00366.

In this case \( V = 36.173 \)
\( h = 29.58 \)
\( t = 16.3^\circ C \).

The equation thus runs:

\[ V_0 = 36.173 \times \frac{29.58}{30} \times \frac{1}{1 + (0.00366 \times 16.5)} \]

\[ V_0 = \frac{1127.91215}{30} \times \frac{1}{1.060390} \]

\[ V_0 = \frac{1127.91215}{31.8117} \]

\[ V_0 = 35.455 \text{ C.C. of nitrogen gas at zero centigrade and normal pressure.} \]

It is found in practice that 27.1 C.C. of nitrogen equal 0.1 gram of urea.
therefore by a simple proportion we may, the amount of area can be easily determined.

\[ 37 : 1 : 35 \frac{45}{5} : 0.1 : x \]

from which \( x = 0.0955 \) gram area in 5 c.c. of urine.

July 14th 1890.

About 10 c.c. of urine collected, similar in every respect to that examined on the 4th of the same month. The odour was however more penetrating and a little like that of boviv.

Estimation of area by Hufner's method

5 c.c. = 50 c.c. Nitrogen.

Temperature: 62°7 = 17° C.

Pressure 29.44 inches of mercury.

By the same formula we have.

\[ V_0 = 5 \times \frac{29.44}{35} \times \frac{1}{1+(0.00366 \times 17)} \]

\[ V_0 = \frac{147.20}{3} \times \frac{1}{1.06822} \]

\[ V_0 = \frac{147.20}{3.18666} = 46.19 \text{ c.c. } N_2. \]

= 0.124 gram of urea in 5 c.c. of urine.

The foregoing qualitative and quan-
litavur estimations may be taken as examples of the nature and constitution of the urine passed in particularly healthy hedgesugs. The amount of area will be seen to vary within wide limits as does also the quantity of urine passed.

July 21st, 1890.

On killing a carniwal the bladder was found to contain 6 c.c.s of yellow, slightly turbid urine, with but slight aromatic smell; on cooling, crystals as above described made their appearance as a heavy precipitate.

Qualitative analysis gave the same results as shown in the examples already given. The quantitative estimation of area gives the following result.

5 c.c.s of urine taken. \( N_2 = 50 \) c.c.

Temperature, 19.41 °C; pressure, 29.85 inches of mercury.

\[
V_0 = \frac{50 \times \frac{29.85}{30} \times \frac{1}{140.00366 \times 19.41}}{}
\]

\[
V_0 = \frac{1492.50}{32.10138} = 46.49 \text{ c.c. } N_2.
\]

= 0.125 gram urea in 5 c.c.s of urine.
From this it will be evident that urine taken direct from the bladder gives results very similar to that collected in the usual way.

The urine of hibernating animals, which is passed only occasionally and in fairly large quantities, is clear of a pale yellow colour, and varies in acidity with the period of hibernation, becoming more and more acid as hibernation goes on.

The urine sometimes deposits a light cloud at the bottom of the vessel, and which on examination is found to consist of uncleaved epithelial cells of various shapes, indicating that some come from the kidney, whilst others come from the bladder; these cells are in various states of decomposition, some being only granular whilst others exhibit oily granules or droplets in varying quantity; much debris of broken down cells may also be found as a granular structureless material. The important point is
that no crystalline deposit such as that seen in summer ever occurs.

The appearance presented by the deposit found in the urine which was taken direct from the bladder of a hedgehog killed in March, at the end of hibernation, is shown in Pl. XL, fig. 79.

I now give the result of an examination of a urine obtained direct from the bladder of an animal killed on January 13th, 1871.

5 c.c. of urine were collected. Colour pale cherry, specific gravity 1.033.

Reaction fairly acid, as shown by titration with caustic soda and phenolphthalein.

An alkaline solution is made by dissolving 40 grams of caustic soda in one litre of distilled water. This is a normal solution of soda and may be represented by the letter N.

If a solution of 4 grams of caustic soda to the litre be made it will be ten times weaker and is called a "deci-normal" solution and is expressed as $\frac{4}{10}$.
10 c.c. of urine are placed in a flask and mixed with some phenolthalein solution, into this a decinormal solution of caustic soda is dropped from a graduated pipette until a pink colour begins to appear, which will happen as soon as the acidity of the urine has just been over neutralized, phenolthalein being pink when alkaline, colourless when acid. The number of c.c. of 0.1N pure solution used is written as the denominator of the fraction and expresses the acidity of the fluid tested.

In this animal there being so little urine 1 c.c. was added to 9 c.c. of distilled water and the titration performed, with the result, that the acidity of the urine was found to be 1/8 which is fairly acid for urine.

On the addition of uracenurea acetaate to the urine a precipitate of phosphates was obtained in fair amount, but on the addition of nitrate of silver only the faintest cloud of chloride of
silver was visible, though sulphates were fairly abundant as shown by the addition of barium chloride. 
Tests for albumin and sugar failed to produce any results, as was also the case with Jaffe's test for uric acid. The Schrader test indicated the presence of uric acid in very small amount.

Urea was estimated quantitatively by Hüfen's process, 1 C.C. of urine yielding 4.2 C.C. of nitrogen at 30 "20 miles pressure and 100°C temperature.
5 C.C. therefore would have given 36.0 C.C. of gas under the same conditions; when corrected for temperature and pressure that would amount to:
\[
V_0 = \frac{\frac{46}{29} \times 0.56}{1.0366} \times \frac{1}{1.0366}
\]
\[
V_0 = \frac{36.33}{1.0366} = 35.047 \text{ C.C. N}_2.
\]

= 0.0944 gram uric acid in 5 C.C. of urine.
Animal killed on March 10th, 1891.
6 C.C. of urine found in the bladder, clear in appearance, of a pale yellow colour and containing some epithelial
debris. When subjected to the tests already detailed in the foregoing paragraphs, it was found to contain phosphates and sulphates in fair abundance, though not in such large quantities as during summer, and chlorides in somewhat less amount. Albumen, sugar and uric acid absent, as was also uric acid, found in the urine of hibernating mammals by Oudin (23). Urea was present in small quantity, and the urine was extremely acid, reddening powerfully the ordinary commercial alkaline blue litmus paper, but the amount was not estimated quantitatively. Urea on estimation gave the following result.

\[ V_0 = \frac{30 \times 29.65}{30} \times \frac{1}{1 + (0.00366 \times 11.5)} \]

\[ V_0 = \frac{29.65}{1.04209} = 28.482 \text{ C.C. N}_2 \]

which represents 0.0767 grams urea in 5 C.C. of urine.
March 5th 1891.

Urine only in very small quantity, the bladder being practically empty.

Urine very acid.

Phosphates abundant, chlorides in small quantity, sulphates apparently absent.

Urea plentiful but could not be estimated. Sugar, albumin and uric acid absent; uric acid, traces only.

From the examples just detailed it will be seen that the reaction of the urine is very acid at the end of hibernation, which agrees with Valentin's statements, rather than with the results obtained by Horvath (1841) in the case of geese. I have already sufficiently considered this subject when speaking of the increased alkalinity of the blood.

With regard to the amount of urea, it will appear that the amount found in the urine of hibernating animals is about the same as that in the urine passed in summer, but when
we come to take into account the quantity of urine passed we shall see that the amount ascertained in July was excreted by the kidneys in one or two days, whilst during hibernation the urine tested had stagnated in the bladder for two or three weeks, or even perhaps for six weeks, and contained the whole of the area excreted during that period. Hence the amount found would have to be distributed evenly over the whole time that had elapsed since the last act of micturition. Therefore the quantity of area excreted per day during the lethargic period is incomparably less than that produced during activity; indicating that the body waste must be very slight during winter in these animals.

These results correspond fairly well with those put forth in elaborate tables by Valentin (152) after testing the urine of the marmot.

With regard to the salts the phosphates seem to be the most a-
bundant to excreted during hibernation, followed closely by the pul-
ephatic, which however in one case ap-
peared to be absent; the chlorids
are always in diminished quantity
as in the bile, they may either be
eliminated in smaller quantity than
in pernum; or reabsorbed into the
system from the urine by the blad-
der wall. Other substances must
be absorbed also, for the distention
of the bladder as pointed out by Ash-
flow is very conducive to the ab-
orption of its contents, and thus the
poisonous elements of the urine would
 tend to pass back again into the
blood; but I suspect that the blad-
der epithelium, which is very thick in
this animal, has some selective power
otherwise we would expect the highly
diffusible crystalline salts of phosho-
ric and sulphuric acid, to disappear
almost entirely from the urine,
which as we have seen is not the
case; and so possibly the passage
of the convulsive principles back into the system may also be prevented by the selective power of the epithelium. At present I have been unable to undertake any experiments to determine these points. Possibly these principles may not be produced during hibernation, but that is surely likely when there is as we know some time metabolism going on.

I have collected my results into a tabular form which will be found on the next page.
<table>
<thead>
<tr>
<th>Date</th>
<th>Condition of animal</th>
<th>Quantity of fluid in C.C.</th>
<th>Time of collection</th>
<th>Result of analysis</th>
<th>Acid</th>
<th>Reaction with conc. Phosphoric acid</th>
<th>Deposit of Ammonium</th>
<th>Deposit, if any</th>
<th>Sugar</th>
<th>Albumin</th>
<th>Chloride</th>
<th>Pepsin</th>
<th>Cupric oxide</th>
<th>Iron</th>
<th>Copper</th>
<th>Calcium</th>
<th>Phosphates</th>
<th>Sulfate</th>
<th>Chlorides</th>
<th>Miscellaneous</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>July 2nd</td>
<td>15-5</td>
<td>10</td>
<td>July 1st, 1890</td>
<td>Nitric acid</td>
<td>0.0975</td>
<td>Abundant</td>
<td>Abundant</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0.124</td>
<td>0.125</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>July 4th, 1890</td>
<td>Direct from bladder</td>
<td>0.0944</td>
<td>Very acid</td>
<td>Fairly abundant</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0.0767</td>
<td>0.0767</td>
<td>None</td>
<td>None</td>
<td>None</td>
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<td>None</td>
</tr>
<tr>
<td>March 9th</td>
<td></td>
<td></td>
<td>June 9th, 1890</td>
<td>Abundant</td>
<td>6</td>
<td>6</td>
<td>Rooted</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0.0767</td>
<td>0.0767</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>March 9th</td>
<td></td>
<td></td>
<td>March 9th, 1891</td>
<td>Abundant</td>
<td>6</td>
<td>6</td>
<td>Rooted</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0.0767</td>
<td>0.0767</td>
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<td>None</td>
</tr>
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Table of the Analysis of the Urine.
Vitality and Muscular Irritability.

All the tissues possess a far greater vitality during hibernation than during the active state, as has already been pointed out by many observers. I shall only mention one or two points in confirmation of this.

In the case of the animal killed on the 14th March 1890, to which chloroform was administered after it had been weakened by fasting, the thorax was opened, the sternum removed, and the apex of the heart severed with the object of allowing free escape of the blood from the body. The heart continued to contract vigorously about 26 times a minute for fully half an hour after the operation, and irregularly for some time longer; finally the beat was confined to the auricles alone, which also ceased after about one hour from the withdrawal of all the blood from the body.
thorax and the want of blood in the body generally the diaphragm performed a powerful inspiratory movement about once every minute, only coming finally to rest about three quarters of an hour after the apparent death of the animal. These movements indicate that the medulla was still active, being stimulated by the want of blood.

The trunk muscles remained irritable to mechanical stimuli for a very much longer period.

An animal killed in a similar manner on March 20th 1891, after half an hour was injected with an injection mass at a temperature of about 30°C; the whole body contracted, the animal which had previously been stretched re-assuming the articular position, suddenly and powerfully, thus the animal's own blood at its normal summer temperature, injected into its vessels during hibernation would act as a powerful muscular stimulant.

In an animal killed on July 25th 1890
in the same manner, the heart ceased beating in less than a quarter of an hour and the diaphragm only made two or three contractions before coming permanently to rest; muscular irritability also passing off very quickly.

With regard to these points it will be seen from the foregoing remarks that during hibernation, these animals closely resemble cold-blooded animals during a state of activity, whilst during summer they resemble other warm-blooded animals which do not hibernate.
What are the causes of hibernation? This question was asked by the French Academy of Sciences at the beginning of the present century, and many investigators have attempted to answer it, but only with varying success; it still remains unanswered at the present time. Buffon and the scientists of his day thought that cold was the chief factor in the production of winter sleep. Mangelli believed that hunger and some anatomical peculiarities had more to do with it than cold, which view was also upheld by Saissy and Prunelle, and others; the differences of structure which they were able to find were very slight, amounting only to slight differences in the size of arteries, veins, and nerves, and narrowness of chest. About 1830 Edwards returned to the theory which looked to cold as the chief cause. The question was again opened by Horwath about
thirty years ago, and without advancing any definite theory of his own, he
strove to cast doubt on the conclusions arrived at by previous writers; lastly
some two years ago Florence imagined that this condition partook of the na-
mur of hypnotic sleep.

It appears to me probable that Marc
qili (56) was not far from the truth when
he stated that hunger was the real
cause. I do not mean to say that
animals are at the present time
actually driven to hibernate through
failure of food, for though ravenous
feeders they retire, as is well known,
soon before their food supply
even begins to show signs of failure;
but the instinct which leads them
to do so must have been acquired
at some period, possibly a not very
remote one, and must have had
a cause, for instinct is nothing more
than experience, acquired and trans-
ded down from one generation to an-
other.
When, owing to gradual change of climate, their food became year by year
scarcer and scarcer during the winter months, had they not adapted them-
selves by variation in a constant direction through a long series of generations to
their gradually altering surroundings, they must inevitably have perished.
Such a gradual change of climate did occur, as geologists tell us, at the close
of the Tertiary epoch; the northern hemisphere changing insensibly but
steadily from a tropical or sub-tropical to a frigid regime.

It is accepted by ornithologists of
the present day that the instinct
of migration was gradually developed
in birds at this time, and that the
prime cause of this annual movement
is not cold but want of food; other-
wise, why do not all migratory birds
pass the whole year in their countries
to which they flock at the approach
of winter, rather than return to us
in summer? The answer is again the
pam; want of food, for the animals on which some birds feed in these tropical regions are subject to a time of re-
pose, during which they are in a torpid condition, termed aestivation, which occurs not in winter, but during 
the hottest part of the year, when the plants and flowers are dry and the 
tender leaves of trees and herbs generally are rare and dry; insects also 
which constitute the food of so many 
migratory birds are wanting during 
the heat of summer in tropical cli-
mates owing to scarcity of food. Did 
not a return movement take place 
these birds which depend on such 
creatures for their daily food would 
as inevitably die in the tropics as 
they would during winter in the arctic 
zone, not from heat or cold, but 
penury of provision.

Let us consider for a moment 
what has been paid by various 
authors upon these phenomena of 
aestivation and migration.
Obstivation, an analogous condition to hibernation which occurs in the tropics cannot be caused by cold.

Frogs, newts, lizards and reptiles (Weissmann) and many fishes such as Siluridae, Labyrinthini, Ophioccephalidae, Dipnoi (Günther) pass the dry season in a perfectly torpid condition.

Protopterus lies without food in a cavity which it excavates in the mud and lines with silt, during the dry season and takes its summer sleep; it is obviously scarcity of food which causes this retirement as it occurs in the hottest climates in the height of summer.

In speaking of migration Allen points out that the reason why birds retire to warmer countries at the approach of winter is not the decline of the temperature but the failure of food; and this is upheld by the fact that the purely insectivorous birds such as the swallows, swifts and fly-catchers are
the earliest to depart and the latest to arrive.
He concludes: (1) that the habit of migration resulted from the change of climate which occurred at a not very remote geological period. (2) That every gradation, in extent of migration, exists between the species and: (3) that failure of food induces a movement towards warmer regions.

Weissmann (357) remarks that did birds not migrate they would perish not from cold but from want of food: as an example, the Cuckoo which feeds on hairy larvaee departs in August when these larvaee pupate as he cannot then find them, whilst other birds such as white-throats, remain with us till September, for they feed on other insects which are still abundant at that time, the woodpecker through an insectorous bird does not migrate because the larvaee on which it chiefly feeds can be obtained during the whole winter.
The counter migration from tropical climates is due to the want of food, for such birds as the Stork cannot find sufficient food when frogs, snakes, etc., have aestivated. They never wait till the supply fails but leave just before the period at which they have learned through generations of accumulated experience, which is instinctive, that the food supply will inevitably diminish.

It seems to me probable that in a like manner in this country animals hibernate in winter from want of food, amphibious reptiles and fish burying themselves in the mud or earth long before the colds of winter set in, but just before the time when their food supply usually tends to fail.

At the end of the tertiary epoch, when the climate of Europe was gradually changing from a sub-tropical to an arctic, such animals as fed on insects and the tender plants of plants would find their food supplies gradually fail, only those
individuals which were the fastest and best nourished would be able to pursue the compulsory fast to which they thus became subjected, and by natural selection only those which tended to vary in this particular direction would pursue; in this way little by little they would acquire a power of storing up food internally which their ancestors did not possess. These animals did not at first no doubt retire till the food entirely failed, but the experience being repeated year after year, and from one generation to another, became an hereditary instinct, which did and still does warn these animals that a dearth of food will come, against which they had better be fully prepared; hence they retire a little in advance of the actual occurrence of scarcity of food, so as not to waste what internal nourishment they already possess in fruitless search for more, their resources being better husbanded in the
hibernating condition than when
returning about.
Belonging for the most part to a class
of animals which live in holes in the
ground they would naturally retire
into them to pass the fasting season,
and thus being in retirement away
from the light and disturbing causes,
would sleep, at first only lightly and
for no great length of time at a stretch,
but gradually the habit would tend
to increase in intensity, until they
ultimately became able to pass long
periods in this condition; moreover
as during sleep the body functions are
less active and as there is consequently
less tissue waste, as the winters became
longer and longer at the approach of
the ice age, only these animals would
survive whose sleep was the deepest and
whose body waste was inconsequence.
least, and the tendency to vary in
this particular direction may have
been so great, that even the vital func-
tions, as time went on, began to be
diminished, till a state was attained whereby the longest possible period of fasting could be passed with the least expenditure of tissue by metabolism, a condition admirably exhibited by hibernating animals, who can do without the high body temperature necessary for the existence of other warm-blooded animals; and in this way again natural selection and heredity came into play through a long series of generations gradually adapting the animals to their altered circumstances.

The climate becoming colder and colder, these animals would be best fitted to survive which collected materials such as grass or fallen leaves in their holes whereby the external air would be less able to reach them, and thus still further diminish the metabolic processes necessary to keep the animal from being frozen, for this reason also such animals as were naturally gregarious would collect together in winter as hedgehogs and bats do.
with the object of preventing undue loss of heat by radiation.

In this way we see how such animals as could not migrate, might by gradual variation become capable of surviving the cold of the ice age, which birds, owing to their power of flight, which gradually became stronger and stronger, were able to escape the death which threatened them by migrating towards the equator.

At the close of the ice age when the continents of Europe, Asia, and North America again became gradually more temperate, it is possible to believe that some hibernating animals would tend to lose the habits which they had acquired at its onset, whilst others in which they had become so deeply rooted would follow the remaining ice up the flanks of the mountains and lie concealed at the present day in such situations, and this supposition is borne out by what we know of the mammoth tribe which inhabits
the highest peaks of mountains in all three continents, being only found in the immediate vicinity of the snow line. There as one would expect are both very deep and very long hibernating animals, as their ancestors were during the ice age, for their conditions have hardly varied even yet. Such hibernating animals however as the hedgehogs, bats and hampstens which did not follow the retreating ice, but remained behind in the plains and valleys, would tend to adapt themselves to their altered environments, and thereby lose something of the intensity and duration of their winter sleep, and that is exactly what we do observe in these animals, concurrent with less storage of fat and less development of the hibernating gland.

Dormice again seem to have still further lost the power of continued winter sleep as well as almost all traces of a hibernating gland; they quickly die not from cold but from want of food.
if not constantly nourished with suitable food, and therefore they are careful to stock their holes before the approach of winter. In very mild winters they can hardly be said to hibernate at all.

Lastly, our little field mouse (Microtus minutus) which passes the winter in a nest, asleep but not hibernating, presents the last link in the chain.

From what has just been stated it will be seen that all gradations of intensity of hibernation exist among the species.

The tendency which some animals exhibit to retire early in the season is well exemplified in our little bat (Vesperugo noctula) which begins to hibernate at the end of July and does not again appear in the spring till late in the following spring. Bell (37) says this animal would appear to have retained for a longer period than any other indigenous species a habit acquired during an earlier geological period.
Manifestly it cannot be cold which produces hibernation in this case, nor ever want of food, for the animalretires before the hottest season has well set in, and long before any possible scarcity of food could arise, but an acquired habit, which has become so strongly an instinct, that the animal has never learned to benefit by its altered conditions, but continues to act just as its ancestors did during the ice age.

Another animal, the lemur of Madagascar (123) becomes torpid from May to December, in a very warm climate, where, though this season seems to be the coldest in the year, the temperature never sinks sufficiently low to produce torpor in any animal, here again therefore it is want of food and not cold which induces the fast tremor to pass the inclement part of the year in sleep.

All true hibernating animals are confined to the northern hemisphere.
as one would expect if what has been already stated be correct; and they all belong to the insectivora, rodents or their near allies, and these are just the classes of animals whose food would be likely to become scarce in winter. Some carnivora are believed to pass the winter in holes without food, but whether they hibernate or not has never been accurately ascertained.

Birds are the only class of animals which exhibits no hibernating species, for the swallow which was formerly supposed to pass the winter in a torpid condition is now known never to do so. This is not in the least astonishing, as owing to their extraordinary powers of locomotion, they have been at all times able to escape death from starvation, by seeking food in distant lands, and migration has done for them what hibernation and restoration do for less favoured tribes.
In conclusion then I believe that the primitive cause of hibernation to have been failure of food occurring at the end of the lentivorous epoch, came which has also produced the migration of birds. The cause of hibernation is also failure of food supplied.

There three plates being various, means adopted by different species to escape the same fate; namely death by starvation.
Histology.
Alimentary Canal.

(39)

Sloper in his lectures on comparative anatomy has given a description of the alimentary canal of the hedgeshog which I have inserted in an abridged form.

Sloper ling long and rather narrow, soft and flexible, the prepuce is placed far back, and is long and large. Dorsal surface is covered all over with fine soft cornical papillae, very uniform in size and character, among these the round fungiform papillae are very conspicuous, being considerably longer and more prominent; they are sparsely scattered all over the surface. There are three large circumvallate papillae placed near together.

Stomach purplish and ovoid, cardiac end depressed somewhat pointed. The thick epithelium lining the esophagus terminates suddenly at the cardiac orifice by a festooned border. The lining membrane of the greater part is soft, loose yellowish and thrown into longitudinal plicate when the organ is contracted, especially near the pyloric end; but almost 3/4 inch from the valve it changes its character.
ters, becoming smooth and more closely adherent. The last named part has more muscular walls than the rest, and the pylorus is formed by a strong circular band of muscular fibers.

The intestinal canal is long and slender, six or seven times the length of the animal, even reaching in some cases to twelve times. There is no cecum nor any perceptible difference externally between the large and small intestines, but they are narrowed at the part which would correspond to the ileum, and somewhat larger toward either extremity. The duodenum at its commencement presents a constricting mass of compound glands (Brunner's) forming a circle round the intestine. There are no velvets or villi on the intestines in the small intestines, but the villi are long for the size of the animal slender and cylindrical and continue to the end of the ileum. The colon, of the whole length, has a serous membrane thicker or softer, and in the lower part thrown into longitudinal ridges. Peyer's patches are well marked in the lower half of the small intestine and of rounded oval form.

Dobson confirms Flower's views.
The Tongue.

The tongue, which is long and rather narrow, varies in thickness in different parts; it is thin at the tip, but gradually increases from before backwards to the middle third, where it suddenly thickens considerably. The organ may, for purposes of description, conveniently be divided into three regions. An anterior portion comprising rather more than a third of the whole tongue, has its dorsal aspect and sides roughened by the presence of numerous small recurved conical papillae, from among which some conspicuous fungiform papillae project; its under surface is rough at the tip, owing to the presence of minute conical papillae, farther back it is only rough at the point of sudden enlargement it becomes quite smooth. A middle portion of about the same length as the anterior exhibits, in its dorsal aspect, a raised central area bounded on each side by a narrow unrelieved
strip similar to the anterior third in structure; the elevated central area is devoid of fungiform papillae its surface being covered only with recurved conical soft papillae, its under surface is smooth possessing no epithelial elevations, the premaxilla however growing from its posterior border. A posterior portion of less extent than either of the other two, may be subdivided into an anterior and a posterior part, of which the former contains the circumvallate papillae, the latter many voncous glands.

There are only three circumvallate papillae arranged in the form of a Y, one posterior and central, two anterior and lateral in position; there are no fungiform papillae in their neighbourhood, only a few conical ones. Papillae foliatae are entirely absent. The trigus joins backward into the epiglottis behind and into the fumuses towards the sides posteriorly where it is smooth and devoid of all papillae.

Mucous Membrane.
Epithelium.

The general surface of the tongue is covered by a stratified squamous epithe-
lium of the ordinary type which is of considerable thickness and dense there-
being only very small spaces between neigh-
boring cells, so that the poorly appearance
characteristic of its deeper layers can only
be seen with very high magnifying
powers. The finger-like processes by which
the inner most layer of cells is attached to
the subjacent fibrous tissue are also
very difficult to see but may occasionally
be made out. A very thin layer of cells
on the surface are alone keratinized, and
through it the conical papillae project.

The tissue is entirely devoid of blood
vessels being surrounded as in other ani-
mals by lymph.

The cells of the deeper layers contain
each a single oval rather conspicuous
nucleus, inside which one or more nu-
cleoli may be seen; in some cells
scattered here and there among the
others the nuclei present a crescenti
mass of deeply stained material lying to one side of a vacuolated phase, closely resembling the nerve terminations described by Haycraft (41) in the carapace of the tortoise. Finger-like processes of the subjacent fibrous tissue project upwards, indicating the lower surface of the epithelium, whereby it has a wavy appearance on section.

Conical or Spurious Papillae.

In sections stained with Ehrlich's acid haematoxylin and benzopurpurin B, & mounted in balsam these papillae present a very striking appearance, as will be seen on looking at fig. Plate I.

The methods which I used in preparing tissues for this research have been collected into a special chapter at the end, in order to save unnecessary repetition. Page 413.

The spurious papillae are exceedingly numerous on the dorsum of the tongue and are entirely composed of epithelial cells which spring from the deepest cells of the
stratum Maltighi covering a papilla of the subjacent fibrous tissue. This germ-
nial layer forms, on the outer aspect, a
strick blunt projection downwards and
backwards into the fibrous papilla, inter-
ting it into the form of a cup. From
this mass of germinal epithelium the
greater part of the cells of the cornial
papilla appear to arise, so that it
seems to be a special arrangement for
the development of the epithelial part of
the papilla. The fibrous tissue beneath
is abundantly supplied with capillary
blood vessels. (p. fig 1. Pl I)

The epithelium of the papilla may
be divided into two portions, an anterior
which springs from the germinal projec-
tion just alluded to, and which consti-
tutes the greater part, and a posterior
portion which springs from the adjacent
growing part of the stratum Maltighi
and of which the tip of the papilla ex-
clusively consists.

If we follow the cells of the anterior
portion in their outwards we shall see
that they gradually increase in size, assume an elongated shape, and that their long axes correspond with that of the papilla itself. (C. fig 1. Pl I) The cells now appear of a bright orange colour, due to their containing granules of varying size of a substance (Eliodin) which stains deeply orange with benzopurpureum. Their nuclei which have also become elongated, stain pale violet with the haematocyanin. These cells come to a point in the middle line of the papilla where they meet peculiar cells of the posterior portion giving rise to a pointed conical mass of orange staining cells in its interior. Above these orange cells and possibly derived from them are, on the anterior aspect of the papilla, a number of long spindle-shaped cells, which stain of a very pale blue, and exhibit small rounded or oval nuclei (c. fig 1. Pl I), they do not however extend as far as its point.

The orange staining cells of the posterior portion take origin at a lower level than
those of the anterior portion, they project upwards and meet there as already described, but do not present any distinct granulation. (†, fig. 1. Pl. I.)

A citron yellow mass of structureless appearance is situated above these cells and extends downwards behind them nearly to the germinal layer of the epithelium, it presents faint striæ suggestive of cell outlines, but no nuclei in this respect resembling the stratum corneum, and is no doubt composed of closely appressed keratinised cells derived from those immediately below.

The tip of the papilla is entirely composed of this material. (‡, fig. 1. Pl. I.) The papilla is distinctly marked off from the surrounding epithelium by a structureless keratinised material continuous on the one hand with that just described, and on the other with the stratum corneum; in section it appears as an irregular branching pavement, very suggestive of polder, seeming to run in and fill all the interstices between the
cells. (3. fig. 1. Pl. I); beneath these the deeper layers of the stratum Malpighii are puckered as if the papilla had been violently thrust through them.

**The Fungiform Papillae.**

The fungiform papillae are much less numerous, and far larger than those just described; they consist of a projection of the fibrous tissue of the mucous membrane which is often carried up above the level of the tips of the fungous papillae covered with a thin layer of epithelium.

In section each papilla presents the appearance of a small pedestal, tipped by a flat table-like piece flush with the anterior surface of the pedicle but projecting considerably beyond its posteriorly, forming an overhanging ledge. (fig. 2. Pl. II). The epithelium which covers the surface of the papilla is uniform in thickness and consists of three layers, an outer of extreme thinness, composed of stratum corneum, continuous with that of the general epithelium of the tongue.
(c. fig. 2 Pl. II) a middle, much thicker staining orange and containing chelidin which gradually tapers off along the sides of the papilla (c. fig. 2 Pl. II), and an inner consisting of one or two layers of germinial cells, continuous with the innermost layer of the stratum Malpighii. An occasional taste bull may be found in the epithelium.

Theformer part of the papilla which is simple is composed of ordinary connective tissue containing numerous corporules and capillary blood vessels; sometimes a bundle of nerve fibres may be seen running up the centre towards the epithelium where they appear to end (h. fig. 2 Pl. II), at other times a few fibres of the vertical muscle of the tongue project for a short distance into its interior.

The Circumvallate Papillae.

Three in number, of large size, wider at the base than at the attached ends, and presenting a slight central depression. These papillae are raised some-
which above the general surface of the tongue, consist of a core of dense connec-
tive tissue covered by a squamous epi-
thelium similar in structure to that of the tongue generally, into which a
few secondary firmos papillae project
without however producing corresponding
elevations on the free surface (t. fig. 3,
Pl. II). This epithelium is of no great
thickness, but firmly clings the sides of
the papilla to line the valley on
both sides, after which it becomes con-
tinuous with the epithelium covering
the remainder of the organ; just at
the point of junction it is extremely
thin (t. fig. 3, Pl. II), and on either side
of the valley presents a smooth inner
surface there being no projections of
the firmos tissue into it in these
regions.

Taste bulbs are situated in the epim-
thelium, they are chiefly confined to the
valley where they obtain ample pro-
defection, a few however may be seen on
the free surface of the papilla (t. fig. 3, Pl. II)
isms on the side of the valley opposite to it; the bulbs are of large size, shaped somewhat like a Spanish onion, and of the usual structure exhibited by such organs in other animals.

The connective tissue of the papilla is very cellular and contains many acini of serum glands (von Elmen's) (e. fig. 3, Pl. II), the ducts of which open into the base of the valley along with the ducts (d. fig. 3, Pl. II) of similar glands situated deeply among the muscle fibers of this part of the tongue; in connection with these glands a few ganglion cells of the usual type may be found in the interior of the papilla. Numerous capillary blood vessels form loops in the lining tissue which also contains lymphatics and nerve fibers going to the taste buds and epithelial cells.

Connective Tissue of the Mucous Membrane.

The fibrous tissue of the mucosa varies in thickness and in density from behind forwards, in the posterior part of the tongue it is thick and divisible into
a looser portion immediately beneath the epithelium, and a thicker portion next the muscle, strands from which pass into the circumvallate papillae. (f. Fig. 3, Pl. II). In the middle third it gradually diminishes in thickness but becomes of equal density throughout; in the tip it is very dense and reduced to a minimum, the muscle fibres being inserted very close to the epithelium. The fibrous tissue projects into the various papillae as already noticed, besides which it forms finger-like projections into the deeper layers of the epithelium, where no papillae exist. On the under surface of the tongue, the connective tissue is less dense and arranged in a thicker layer.

The connective tissue corpuscles are of the ordinary type and lie in branching spaces as may be seen in picro-carmine specimens, as they fill the spaces they are no doubt branched also. There are very few wandering cells and only
a few lymph capillaries, coarsely granular cells may also be recognized here and there.

Numerous arteries and veins are present in the deeper layers of the mucosa which give rise to capillary loops for the supply of the epithelium. A small vein situated on each side of the circumvallate papillae is conspicuous (cf. fig. 3, Pl. II). In the posterior third of the tongue isolated ganglion cells may be seen in the fibrous tissue, each surrounded by a few densely packed fibers, forming a pseudo-capsule; isolated acini of von Ebner's glands may also be seen in it in this region (cf. fig. 3, Pl. II), as well as the acini of mucous glands towards the sides.

Body of Tongue

Connective tissue.

A vertical septum, the median raphe, divides the tongue into two lateral halves; it extends from the floor to the dorsum of the organ in the middle third, where it splits to enclose the longitudinal
pommental cylindrical mass of muscle fibres which produces the central elevation already alluded to, but does not extend so far in the remainder of the tongue. On section it appears as a thin irregular, zigzag line of dense fibrous tissue from either side of which numerous muscle fibres spring. A few blood vessels may be seen in it in its lowest part.

The connective tissue between the muscle fibres is loose, cellular, and contains much fat, especially deep down in the posterior part of the tongue. This connective tissue is rendered very conspicuous by the great number of coarsely granular corpuscles which it contains. The granules of these cells stain very deeply with acid haematoxylin and all basic anilin dyes, and are situated entirely in the protoplasm, none being visible in the nucleus which usually refuses to stain, and in which a single, deeply staining nucleolus may sometimes be found.
These coarsely granular cells "Plasmazellen" of Waldeyer appear to spring from small, rounded, nucleated connective tissue corpuscles, similar to those which develop into fat cells; they may however even at this early stage be readily distinguished from all other forms of connective tissue corpuscles by exhibiting one or two large granules in their protoplasm, having all the characteristics shown by those which fill the adult cells. (a, fig. 2, Pl. III). There are in connective tissue generally other granular cells which can only be distinguished from the above by the behaviour of their granules towards various anilin dyes; for example the "Montgellien" or "Eosinophilous" cells of Ehrlich (b3) which are filled with large granules having an affinity only for acid anilin dyes, and especially for acid eosin; again, some cells contain fine granules which may stain either with basic or acid anilin dyes, but never with both, and poor.

There seems to be no evidence of a
transformation of these cells into fat cells, as was suggested by Waldenström (42), they
seem simply to increase in size, to accumulate more granules in their protoplasm and to accommodate themselves to any shaped space in which they may happen to lie, they are therefore oval, round, polyhedral, or stellate according to circumstances (a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, etc.); later they appear to spread themselves out somewhat, lose their granules except in the neighborhood of the nucleus, where they remain some time longer, but eventually these disappear also, and the cell then loses completely its characteristics and cannot be distinguished from an ordinary fixed connective tissue corpuscle (f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, etc.).

These cells are by no means confined to the connective tissue of the lung, but are numerous all over the body, and especially so in the neighborhood of blood vessels where they may often be seen in all stages of growth. Their function is at present unknown,
they appear to be more numerous in animals which have been carefully fed, after having been made to fast for some time [Kowbutt-Daskiewicz], which has suggested that they may be merely over-fed ordinary connective tissue components. They appear to be most numerous in the animal soon after it has begun again to feed in spring, but they never entirely disappear from the body, and in the tongue they seem to be as numerous in winter as in summer. They may possibly be of service in the nutrition of the body, as towards the end of hibernation, in young, plasma cells can be seen, only in adults, and cells which have lost many of their granules; in spring and autumn on the other hand many young cells are to be seen, but effort ones are rare. Their large number in the hedgehog also suggests that they must preserve nutrition, possibly the granules which they contain may be gradually used up during hibernation.
thereby supplying the hibernating animal with some material essential to its well-being, and which, owing to its torpid condition, it is at the time unable to procure.

The connective tissue of the tongue is very vascular, many nerves run in it, and it is continuous with that of the mucous membrane in all situations where they come in contact.

Muscles.

The tongue possesses extrinsic as well as intrinsic muscles, of the former nothing need be said here; the latter consist in transverse fibres which pass outwards from the median paphe to the connective tissue at the sides of the tongue; the vertical fibres which pass upwards to be united by muscle tendons into the connective tissue of the dorsum of the organ; the superficial and and deep lingual fibres which are in their usual position, and well developed; and in the centre
of the middle third near the dorsum, a cylindrical bundle which forms two wards to be inserted into the anterior part of the organ, bundle of muscle fibres which apparently causes the smooth elevation of the dorsum of the tongue, which has already been referred to several times.

The muscle is of the ordinary striped variety, but exhibits a large quantity of nuclei under the pericolemma, disposed in an irregular manner, a similar arrangement to that which prevails in the skeletal muscles of the same animal. The fibres end in short fibrous tendons.

At the base of the tongue its posterior part a few curious muscle fibres may be seen exhibiting chains of nuclei similar to those to be described in the skin; page 373.

The fibres of the superficial lingual muscle exhibit several varieties, as may be seen in transverse sections.

1) The most numerous fibres consist of very fine fibrils, and possess nuclei only
under the parcolemma, they call for no further comment. (a, fig. 6 Pl. IV).

(2) Coarsely fibrillated fibres of which a few only exist scattered here and there among the others, their nuclei as usual are under the parcolemma (a, fig. 4 Pl. IV).

(3) Cuneiform fibres found scattered in an isolated manner or in groups allow the tongue. Each consists in a central core of ordinarv striated muscle, with fine fibrils, surrounded by, but slightly separated from, a tubular sheath of striated muscle, the fibres of which run at right angles to those of the core, sometimes a nucleus may be seen in the space between this sheath and the core. Outside the sheath there is a varying quantity of undifferentiated granular protoplasm containing nuclei, which are often angular in appearance. (b, fig. 68 Pl. IV). These fibres are at times very numerous, and though I searched diligently, I failed to find any vestige of them in longitudinal sections, though
they are always to be seen in transverse sections made through the posterior third of the tongue.

If the mechanics of such a fibre be studied, it will be seen that if the central core were alone to contract, the fibre as a whole would be shortened; if the sheath were alone to contract, the fibre as a whole would be lengthened; if both were to contract at the same time, no movement would probably result. The fibres appear to be too few however to be of much use in the movements of the tongue; I am rather inclined to think that these fibres are imperfectly developed like Pacinian fibres in the beard, and that therefore no special significance must be attributed to their peculiar place.

Blood Vessels and Nerves.

There are three chief arteries in the tongue. One with a vein above and below it, situated deep down in the median raphe, has a nerve on either side of it which is situated not in the raphe.
but in the loose connective tissue close to it.

In other blood vessels with their accompanying veins enter the tongue, one at either side, and converge towards the central artery as they pass forwards towards the tip of the organ; they are also accompanied by nerves.

The blood vessels break up into small branches of supply for the muscles and connective tissue, the capillary vessels form loops in the fibrous papillae under the epithelium. The only peculiar feature of these vessels is that the endothelial cells of their inner coats are very long and possess their spindle-shaped nuclei, very much resembling those of unstriped muscle fibres.

The nerves accompany the arteries, ram between the muscles, no doubt supplying them, and pass to the epithelium and taste bulbs. Ganglia may be found near the nerves in the region of the porous glands. They are composed of ordinary ganglion cells of the peripheral
type, the so-called unipolar cells, which are surrounded by a capsule lined with epithelium, the nuclei of which can be seen. The cells are granular, present a vesicular nucleus which contains a nucleolus and in which may sometimes be seen an endonucleolus.

One large sized ganglion in mass may be seen at the sides of the tongue in relation to the mucous glands, which are situated in its posterior extremity. Isolated ganglion cells are found scattered in the connective tissue of the mucosa and papilla circumvallata as already mentioned, in which case they have a thickened fibrous pseudo capsule around them.

In gold chloride preparations, the nerves may be traced up into the circumvallate papillae, where they lose their medullary sheaths and pass to the taste buds. Each taste bud is only found in certain parts of the tongue and not over its surface, though there is a keen sense of taste for certain phe-
stances in the tip, there are very few if any taste buds in this region, which led me to search for some other mode of termination of the fibres of the gustatory nerve. With this intention I treated some portions of the tip of a fresh tongue with gold chloride, using various methods, and found that Lüttke's method as modified by Ramdohr, gives the best results.

On looking over a number of sections prepared in this way, I found that the nerves which are abundantly distributed to the epithelium lose their medullary sheath very soon before entering the stratum Malpighii, in which they may be traced for some little distance, running between the cells. It is difficult to state exactly how they end, but I have figured (Fig. 5 Pl. III) several epithelial nuclei in which nerve fibrils appear to terminate in a more or less marked demilune of nervous matter developed at one end or side of the nucleus. Such appearances are by no means
common, and isolated would be of no significance, but on listening through a
number of sections quite a quantity of such terminations may be more or less
distinctly made out. Now in speaking
of the epithelium I have mentioned that
in hardened sections some of the nuclei
of the stratum Malpighii present an ap-
pearance suggestive of nerve termina-
tions as the nuclei appear clear with the ex-
ception of a small, almost penellinear,
deeply staining portion at one side, and
as seen with gold chloride some non-
medullated nerve filaments and in some
such nuclei, I think it is highly pro-
bable that all of these or at least the
greater part of them may be the ter-
minalparts of nerve fibres, and this seems
all the more probable, seeing that,
beside the great sensitiveness of the
tip of the tongue to tactile impressions,
there are hardly any tactile disks pre-
ent in the oral mucous tissue.
I believe these endings to be very rich some
being gustatory in function, and some,
probably the greater portion, being tactile in function, whereby they resemble the tactile discs of Bayliss (46) in function as well as in appearance.

**Glands.**

Two kinds of glands are found in the tongue, pretons and mesons.

The preton glands of von Ebner are very large and entirely confined to the posterior third of the organ, where they extend deeply between the muscle fibres.

The ducts, which branch frequently, open into the bottoms of the valleys of the circumvallate papillae. Some gland units are also found in the mesons and in the papillae themselves.

They are compound tubular glands with a central lumen surrounded by granular columnar cells, with a deeply placed nucleus of oval shape, containing a small nucleolus. Outside the cells there is an endothelial basement membrane. The duct is lined by a single layer of cubical epithelial cells with clear protoplasm, and central
In the submucosa, there is a basement membrane outside the cells.

The glands are remarkable for their large size and the depth to which they penetrate the tongue; many ganglion cells are in connection with them, and they are liberally supplied with blood vessels.

There are no plasma cells in their immediate neighborhood.

Mucous glands.

They are confined to the sides and hindermost part of the tongue, where they rival the serous glands in size, extending deeply down between the muscle fibres through half its thickness.

They are compound tubular glands, the acini of which form a distinct central lumen lined by columnar cells, the nuclei of which are pressed down to the attached ends of the cells, which are usually clear. There is a basement membrane outside the cells. The ducts, which dilate somewhat before reaching the surface, are lined by cubical somewhat granular cells, m-
located upon a basement membrane.
there are ganglia in connection with these glands as well as numerous blood vessels.

Changes exhibited by the various structures found in this organ during hibernation.

The chief differences are observable in the glands, but all the tissues show a much greater reaction to staining agents during summer, when in a state of great activity, than in winter, when they are in a passive condition; and this holds true of almost every tissue of the body, its taking usually twice as long to obtain the same effect with the same dyes, in the case of tissues taken from a hibernating animal, as it does in the case of tissues obtained from a similar animal killed during the active period of its existence.

If we compare two sections of tongue stained with procion-xamine and mounted in Vector's solution, one from an...
animal killed in summer, the other from a hibernating one, we shall see that the cells of the peroral glands in the former stain of a yellow colour, are not very granular, only slightly turbid, and contain an evident brightly stained nucleus, in which it is difficult to see a nucleolus; whilst those of the latter stain of a reddish tinge, are very granular and turgid; their nucleus being less evident, of a duller colour, but containing a very conspicuous smaller nucleolus.

Identical sections stained with Edel's acid haematocyanin, benzophenone 15 and mounted in balsam, show when compared, that in summer the cells of these glands stain yellow whilst in winter they assume a reddish hue, with a more granular appearance of the protoplasm.

In the first two sections the cells of the mucous glands stain yellow and present an indistinct protoplasmic network during activity, while in winter
they are red and possess a very distinct and close network; in the other two, the cells during summer stain intensely purple blue which quite obscures their structure, suggesting them to be full of mucin, whilst in winter they become only faintly stained with blue and exhibit a close protoplasmic network which assumes an orange tint. The ducts of these glands are filled with mucin, which stains intensely blue, during activity, whilst during hibernation they only contain some substance which stains orange and which therefore cannot be mucin. The cells of the ducts exhibit no material change.

The differences above detailed are simply such as would result from a greater or less activity of the parts.

With regard to the connective tissue it is slightly more cellular looking in summer than in winter, but the number of plasma cells is greater during activity than during the period.
of winter sleep, and these cells increase
may be seen in all stages of development.
whereas in winter only adults are
seen in any quantity.
The other tissues appear to undergo
no great change.
The Oesophagus.

The oesophagus consists of three coats:—
A mucous, a submucous and a muscular.
A, B, C, fig. 8, Pl. V.

The mucous membrane is very thick compared with the other coats, owing to the great development of its muscular mucosa.

Epithelium. (E)

The mucous membrane is lined internally by a thick, stratified squamous epithelium, similar to that formed by other animals in this region; it is however unusually thick and the cells of its deep layers exhibit only very short protoplasmic bridges; it is devoid of blood vessels depending entirely for its nourishment on the percolation of lymph through it.

Cortex vera.

Papillae of the dermis project into the under surface of the epithelium, are composed of dense fibrous tissue and contain numerous loops of capillary
blood vessels. The cæcum vero which is very thick has in its outer part numbers of thick bundles of large un-striped muscle fibres running longitudinally, with little connective tissue between them. (M.M.) This great development of the muscularis mucosae may be compensatory for the want of mucous glands which are absent from the whole length of the tube, except at its pharyngeal end, and at its opening into the stomach, where one or two mucous acini may be found running among the muscle fibres, and not as one would expect in the sub-mucous coat. (M., fig. 10 Pl. VII). This arrangement of muscles is similar to that which obtains in certain portions of the cat's oesophagus, where the muscularis mucosae is extraordinarily developed. At the junction of the tube with the stomach this mass of muscle gradually narrows down into a thin band composed of two layers continuous with the muscularis mucosae of the stomach. The time
is well supplied with blood vessels through-
out.

Lymph follicular tissue is also absent
from the esophagus except at its junc-
tion with the stomach where a few
politary glands may be seen projecting
into the fimbria papillae. They consist
of masses of lymph corpuscles crowded
together in the meshes of the tissue
in which they are situated and
become gradually less numerous
from the center outwards, the glands
are devoid of any special stroma and
of a capsule, by their rapid develop-
ment they press the connective tis-
ue to one side thus forcing the
fibres together, which may give it the
appearance of a pseudo-capsule. They
appear therefore to be very different
bodies to those described in the
textbooks as being found in the in-
testines, both appear similar to the
solitary glands as described by Prof.
Rutherford in his lectures on the
structure of the intestine, and which
applies more especially to the cat. These glands are well supplied by
blood vessels.

Sub-auricular coat. (Fig. 5. Pl. 1.)

This is a comparatively thin coat, consisting of a somewhat dense fibrous tissue;
as is the rule throughout the whole alimentary canal of these animals, contain-
ing blood vessels, nerves a few ganglion
cells of Menon's figure, and a little
fat. Here and there a striped muscle
fibre may be seen in it, as if it were
escaped from the adjacent muscular
coad. One of these adventitious fibres
(Fig. 9. Pl. 1.) is peculiar in having three
nuclei each surrounded by a little
undifferentiated protoplasm, situated
among the fibres, and separated by
a few of them from one another; there
are also several similar nuclei (a) situ-
ated under theparacoloeum (5).

This fibre triangle belonging to a mammal
is similar to that of the amphibian
in having nuclei among its fibres, and
thereby also differs from the fibres.
of the adjacent muscular coat of the oesophagus and from the muscles of the body generally, with the exception of those to be described in certain parts of the pericardium ecmous.

Muscular Coat.

Composed of two layers of obliquely placed striped muscular fibres, which extend through out its whole length and even penetrate for some little distance among the non-stripped muscle fibres of the outer coat of the stomach. The muscle is of the ordinary striped variety and calls for no further comment.

At the junction of the oesophagus with the stomach there are a few curious muscle fibres with chains of nuclei already alluded to, and which will be fully described when dealing with the skin. They may be easily recognised as they stain less deeply than the ordinary muscle fibres. A few ganglion cells of Auerbach's plexus may be seen between the inner and outer muscular coats; outside the muscle
there is a thin layer of ordinary fibrous tissue containing blood vessels and a few nerves.

Changes which these tissues exhibit during hibernation are slight; the tissues stain less readily than in summer; the connective tissue is less cellular, and contains hardly a trace of plasma cells, though these exist in the connective tissue of the mucous and submucous coats, in considerable quantities, during the active period.
The Stomach.

The stomach, which somewhat resembles that of man in shape, is composed of four coats: a mucous, a sub-mucous, a muscular, and a peritoneal.

After hardening, that is in a very contracted, and somewhat phlegmatic condition, the organ measures 7.6 centimeters along its greatest curvature; of this, 0.83 centimeters is occupied by the pyloric part of the organ.

Mucous Membrane.

The mucous membrane is thrown into numerous transverse folds, due to contraction of the muscular coat of the stomach, so that on section numerous ridges appear; independently, however, of which, the tissue is not of uniform thickness throughout, but presents thinner and thicker parts in waves along the whole organ, giving an undulating aspect to a section of the tissue.

The mucous membrane presents un-
merous glands which are tubular in structure, and may be either simple or compound. The cells lining these tubes vary in different parts of the mucous membrane.

Near the oesophagus, and immediately following on the abrupt termination of its stratified epithelium, a few glands may be found, the cells of which resemble those of the glands of the pyloric end of the stomach. (p. fig. 10 Pl. VI) These glands have short ducts similar to those of the cardiac glands, and a gradual transition exists between the two varieties.

**The Cardiac Glands.**

The cardiac glands are longer or shorter tubular glands, usually simple, sometimes compound, two or more acini opening into one duct.

I measured the length of the various parts of the cardiac glands with a micrometer, and give the results obtained in the following table.
in which the exact measurement of the various parts of three glands is given, one of great length, one very short, and one of medium size.

<table>
<thead>
<tr>
<th>Character of Gland</th>
<th>Length of Duct in Millimeters</th>
<th>Length of Neck of Gland in Millimeters</th>
<th>Length of Body of Gland from Base to Middle in Millimeters</th>
<th>Total length of Gland in Millimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long.</td>
<td>0.16</td>
<td>0.06</td>
<td>0.46</td>
<td>0.70</td>
</tr>
<tr>
<td>Medium</td>
<td>0.20</td>
<td>0.06</td>
<td>0.34</td>
<td>0.60</td>
</tr>
<tr>
<td>Short.</td>
<td>0.08</td>
<td>0.02</td>
<td>0.32</td>
<td>0.42</td>
</tr>
</tbody>
</table>

The glands are all about the same breadth, which at the thickest part is about 0.04 millimeter.

The ducts are short, with a wide lumen lined by a single layer of clear columnar cells, the appearances presented by which vary with their condition. When the cells have been active for a time, that is when their contents have been discharged into the stomach, the cells present a fine granular appearance due to their fine meshed protoplasmic network which stains of an orange colour with benzopurpurine B. The
cells themselves appear angular, and the nucleus which is oval and placed near the attached end is full and exhibits a nuclear network. (c, fig. 11, Pl. VII)

When however the cell has been at rest for some time, it has a different appearance; the angles are to a certain extent rounded off, and the whole cell is much less granular, a fine network is visible in it, the strands of which appear stretched. This clear appearance is due to the cell containing a substance mucicarin, antecedent to mucin, and which stains of a faint blue violet with acid haematoxylin; at the same time the nucleus recedes further into the attached end of the cell, and if the cell be very full, has the appearance of a shrivelled body, often of a crescentic shape. (d, and e, fig. 11, Pl. VII).

It is stated by Foster (46) that these cells burst open at their free ends
thereby allowing their contents to escape into the cavity of the stomach, much in the same way as the chalice cells of the small intestine are paid to do, I have diligently looked for such burst cells with plugs of mucus projecting from their open ends as in fig. 11 pl. VII, which is a chalice cell of the duodenum, but I have totally failed to observe even a single one.

Between the attached ends of these cells a few small nucleated cells may be occasionally seen, which are paid to be replacement cells (Foster 46); others still smaller bear the appearance of lymph corpuscles, and are true wandering cells. The whole epithelium is placed upon a basement membrane probably composed, as stated by Foster 46, of somewhat flattened out cells of the subjacent adenoid reticulum.

In the cardiac glands the ducts are
Very short, as has already been pointed out, and are proceed immediately by what is known as the neck, here the lumen which is small is lined by columnar or polyhedral clear cells more granular than those of the ducts and shorter, they present a single round nucleus which is small and exhibits a wide-meshed network that stains blue with acid hematoxylin. These cells are difficult to see and hence have been named "adenomas" or from their position "central cells; they extend as a lining through onto the entire length of the gland proper, immediately surrounding the lumen which widens out slightly below.

Outside these cells in the deeper parts of the gland are found numerous large, rounded, coarsely granular cells, which have a special affinity for acid anilin dyes, such as benzopurpuric B. and acid eosin, they are very conspicuous, and by
their extraordinary number, completely cover up the central cells in pinhole views of the glands. These "somal" or "decomorphous" cells exhibit a well-marked, centrally placed, round nucleus, containing a nuclear network, and possessing an envelope; the cell appears very granular, owing no doubt to a fine-meshed protoplasmic network, has an envelope which is attached to the well-marked basement membrane, that surrounds the secreting part of the gland. This membrane forms little crypts or locali for the somal cells so that each one appears to lie in a little compartment especially reserved for it. Occasionally one of these cells may be seen in the neck of the glands, but this is by no means the general rule.

As one passes from the oesophagus, then cells first make their appearance at the deep, closed ends of the glands, but soon extend up to the necks,
as one goes onwards, where the cardiac part of the stomach joins into
the pyloric end, these glands cease suddenly, and are at once preceded
by the pyloric.

**Pyloric glands.**

They are tubular glands, often com-
posed, with long wide ducts, and short
secreting portions. The ducts are lined
by the same clear mucinogen pro-
ducing cells that line those of the
cardiac glands. The secreting portion
of the gland has its narrow lumen
lined by columnar cells which
resemble very closely those found
in the acini of Brunner's glands of
the duodenum, more closely indeed
than the central cells of the cardiac
glands. They are columnar, faintly
granular, owing to a close-woven
fine, protoplasmic network which stains
only faintly violet with acid hema-
trypsin, the protoplasm itself tending
to stain orange with the benzo-pur-
phenin B, which that of the ciliated glo-
mal glands.
ous cells never does, the nucleus also is situated nearer the attached ends of the cells than are those of the above mentioned ones. Outside these cells there is a basement membrane.

The whole of this mucous membrane containing these pyloric glands when measured along its folds, in hardened preparations, rarely .21 centimeters in longitudinal extent.

Epithelium covering the general

According to Foster (46), Klein (47), Stirling (48) and others the epithelium covering the surface of the stomach is the same as that which lines the duct of the various glands. On the other hand Prof. Rutherford has taught for some time that, in the cat's stomach at any rate, this surface is lined by ordinary columnar cells similar to those of the intestine. In the heshog, these long columnar cells are very conspicuous especially at the pyloric end, where they may even extend
some little way into the ducts. They are elongated, of the ordinary type, longer than the mucigen producing cells, and exhibit a clear, though var.
var. stained hem, a protoplasm with a fine network staining orange with hemopurpurin 15, and a large oval nucleus placed near the center of
the cell. q. fig. 11 Pl. VII. It is no doubt through these cells that absorption takes
place in the stomach.

The connective tissue of the
mucous membrane consists of an
adenoid peticulum of branching
nucleated cells, the meshes of which con-
tain numerous lymph corpuscles
and some wandering cells. Numerous
capillary blood vessels pass up in it be-
tween the glands, and end in blood-
doors just under the epithelium; arti-
ridges of small caliber may be seen in
it, just internal to the muscularis
mucosae. The cells of this reticulum
appear to be flattened out into en-
dotheiial plates forming a part of
basement membrane for the columnar epithelial cells, a true endothelial basement membrane does not appear to exist here. Occasional polycystic glands may be met with in this adenoid tissue.

**Muscularis Mucosae.**

The mucous membrane is limited externally by a muscularis mucosae disposed in two layers, the cells of which run obliquely. Bundles of non-striated muscle fibres spring from these layers, run up in the adenoid reticulum between the glands, becoming attached to it alone, but also forming a ring round the mouths of the glands. The muscle is continuous at the oesophageal end of the stomach with the muscularis mucosae of that organ (mm. fig. 10 Pl. VII) and at the pyloric end at intervals with the inner muscular coat of the stomach, as well as with the muscularis mucosae of the duodenum (mm. fig. 15 Pl. IX).

In some cases, in the muscularis mucosae of the oesophageal end, just
at the junction, before the muscle has quite become narrowed down, a periaxial gland may be seen, similar in structure to von Ebner's glands of the tongue, which opens on the surface next to the absorptive termination of the esophageal epithelium by a long duct lined by cuboidal epithelial cells, which pierces the whole thickness of the mucous membrane. (s. fig. 10 Pl. VI.

**Sub-mucous coat.**

Consists of ordinary fibrous tissue deeper near the mucous but looser near the muscular coat; it is not nearly so thick as either of these except in the folds, where it attains a certain thickness. The fibres are such as are found usually in ordinary connective tissue, but the cells of which pig helaitd may be made out require special attention.

1. Ordinary plate-like connective corpuscles with a large oval nucleus that stains conspicuously by a pale blue colour with acid haematoxylin; the plate-like part of the cell hardly staining at all. These cells are key for the
most numerous and may often be seen clasping the fibres. (e, fig. 12 Pl. VIII)

(2) A plate-like cell slightly smaller than the above, with a conspicuous oval nucleus, a plate-like expansion finely granular in appearance which stains orange with benz pyrurin &. They are far less numerous than the ordinary connective tissue corpuscles, but may sometimes be seen clasping the fibres. (b, fig. 12 Pl. VIII)

(3) Plate-like cells very few in number, smaller than the last but like their finely granular, the plate-like expansion staining finely with acid haematoxylin. The nucleus of these cells is smaller and more rounded than those of the other two. (c, fig. 12 Pl. VIII)

(4) Plasma Cells. Coarsely granular corpuscles of irregular shape with a small oval or rounded nucleus staining of a faint blue colour with acid haematoxylin, and with a protoplasm thickly studded with large granules that stain deeply violet with the same dye.
there are very few of these. (d. fig. 12. Pl. VIII)

(5) Wandering cells. Small rounded cells like white blood corpuscles with two or more nuclei, often bilobed; the cell substance stains deeply yellow with

hemopurinine B. (e. fig. 12. Pl. VIII). In some cases these cells are very numer-

ous, in others they are seen only here and there.

(6) In the neighborhood of solitary glands when these exist, both varieties

of the small nucleated cells characteristic of lymph follicular tissue may

be seen, with their round nuclei deeply stained with acid haematoxylin.

Häckerlein has described cells 1, 4, 5,

and 6 as occurring in the connective tissue

of the intestine, but does not men-

tion 2 and 3.

The submucous coat contains numer-

ous blood vessels, lymphatic vessels and a

ganglia of Meissner's plexus; it is con-

tinuous at the cardia and with the

submucous coat of the esophagus, and

at the pyloric end, with that of the
duodenum from which it is occasionally separated by muscular tissue.

The Muscular Coat.

Consists of two layers of non-striped muscle, the inner of which is circular and thick, (i.e., fig. 15—Pl. I.) whilst the outer is oblique, and thinner than the other (om., fig. 15—Pl. I.).

The inner coat is thickened slightly at the cardiac end to form a cardiac sphincter, but the sphincter action is here no doubt chiefly brought about by the greatly thickened muscularis mucosae of the oesophagus.

At the pyloric end, where the coat is very thick, the circularly placed muscle fibres are raised into a thick sphincter for the stomach, (i.e., fig. 15—Pl. I.) fusing more or less with the fibres of the outer coat and prolonged up as a thin partition of muscle through the submucous coat to the muscularis mucosae, (om., fig. 15—Pl. I.) with which it now and again becomes continuous.

This projection has a straight, well-like
surface towards the duodenum, but slopes down in a gentle curve on the stomach side.
Between the two muscle coats, a somewhat large number of ganglia of Auerbach's plexus may be seen, as also numerous blood vessels.
The peritoneal coat consists of an inner sheet or backing of ordinary connective tissue covered externally with a single layer of endothelial cells.

Changes observed in the Stomach during hibernation.
All parts of the organ seem more readily as already pointed out, in summer than in winter.
Looking at the epithelium, the most obvious difference occurs in the parietal cells of the cardiac glands, as already stated, they stain differentially with great ease in summer and consequently appear very numerous, whilst in the hibernating condition they are
only slightly affected by aniline dyes, and require to be handled for, being by no means very conspicuous objects. From this tendency to remain unstained they appear to be far less numerous than in permum; they are also of smaller size and seem filled with larger granules, or the network of which the granules are only the optical expression is more conspicuous owing to the cells being less distended. Their nuclei show no change.

The central cells of the glands also exhibit some slight changes consequent upon their want of activity: they are of larger size, less elongated in shape with more rounded edges; otherwise they appear the same as in permum. These changes are no doubt simply to be accounted for by variation in the activity of the different cells.

The cells lining the ducts are larger, more distended and clearer, their contents stain more blue with acid haematoxylin and their nuclei consequent on the greater distention
If the cells are pushed further down towards their attached ends (as shown in fig. 11 Pl. VII.)

In summer when the cells may be presumed to be in constant activity, their nuclei are less deeply placed; the protoplasm is much more granular giving the cells a somewhat clumpy aspect, and their contents are less deeply stainable with acid hematoxylin, being probably discharged as soon as the cells acquire a certain amount of distention; in winter this discharge seems to take place much more sluggishly, hence the great distention seen in the cells.

Many of the columnar cells lining the general surface of the organ appear distended with mucus and to lose their hem during hibernation. The surface of the stomach is covered by a thin layer of mucus containing debris of epithelial cells, resulting from the natural death rate of the cells, in summer this layer of mucus is either very thin or absent altogether.
I have never at any time seen the thick layer of mucus and other material mentioned by Valentine as occurring commonly in the stomach of mammals during the first half of hibernation.

The most remarkable change in the stomach resulting from winter sleep in these animals is seen in the connective tissue both of the mucus and submucous coats; it consists in an extraordinary increase in the number of wandering cells, which may be seen lying in little linear groups of three and four between the fibers of the submucous connective tissue. The whole tissue is crowded with them giving it a peculiar appearance; in some situations near the larger blood vessels these cells are so numerous and so closely packed together as to give rise to a mass of cells not unlike a salivary gland, but distinguishable from it by the larger size of the cells and the affinity which they exhibit for various acid anilin dyes.
It is evident from their behaviour to staining agents, from their close relations with the blood vessels, and from their histological characteristics, that these cells are merely migratory white blood corpuscles. They are mostly round or oval in shape, usually exhibiting well-marked nuclei, each with a nucleolus which stains deeply with acid haematoxylin; the nucleus taking on a pale violet colour with the same dye, and containing a delicate nuclear network. The cell substance, which is homogenous or juxta granular, stains of a pale straw colour with benzidine B, and of a bright purple with eosin; with this latter dye the cells seem very granular and appear to be identical with the "monocytes" or eosinophile cells of Ehrlich, which were considered by Heidenhain (1889) to be in a state of degeneration.

That these cells are not identical with those of lymph follicular tissue is evident from their relative size and...
from the fact that the cells of lymph follicular tissue appear to be unaffected by acid cuinilis, in cases where they stain at all, preferring to prefer the haematoxylin; their nuclei which are always conspicuous, filling as they do almost the whole cell, stain uniformly with haematoxylin or with iodine greens, and other similar staining agents. (fig. 13 Pl. VIII), whilst the wandering cells stain deeply with acid cuinilis, exhibit several nucleoli in which nucleoli may always be seen, indeed a wandering cell may sometimes be seen inside a simple lymph follicle into which it has wandered, and is then recognizable with great ease. (m. fig. 13 Pl. VIII)

The wandering cells vary in size, some being very small with only a single nucleus surrounded by a small amount of protoplasm, (a. fig. 14 Pl. IX) others are much larger with conspicuous bi- or tri-lobed nucleus exhibiting two nucleoli one at either pole of the lobulated...
nucleus. (c, d, e fig. 14 Pl. IX), or occasionally the nucleus may be dumb-bell shaped with a nucleolus in each head (f. fig. 14 Pl. IX) or again the cell may contain two distinct nuclei each with its included nucleolus, nuclei which may be oval or elongate in shape and separated from one another by a greater or less interval (g. h. i. j. k. fig. 14 Pl. IX) and lasting some cells may be found with a pleat-like constriction occurring in the protoplasm between the two nuclei as if about to divide (l. fig. 14 Pl. IX). In one case I observed two cells quite close to one another, each with a single nucleus, but so closely placed as to suggest the very recent division of a single mother cell. (m. fig. 14 Pl. IX)

I think there can be very little doubt from what has just been said that the white blood corpuscles wander from the blood vessels into the connective tissue, and that once there they multiply and divide, the fact that I have not been able
to demonstrate any hemopoietic figures in them does not militate greatly against this theory, for as far as we are aware at present, there are no evident mitotic figures visible in white blood corpuscles multiplying in the blood stream.

If this be accepted then Heidenhain's statement, that these cells in the pub mucous tissue of the alimentary canal are degenerating cannot be held, but they must be looked upon as white blood corpuscles still in an active condition and quite capable of reproducing their kind in their new abode. No doubt they have undergone some modification in chemical character or they would not stain with certain dyes in a different way to the white corpuscles still in the blood stream; fitting them no doubt to play some important role in the nutrition of the animal during hibernation.

It may also be further stated in th
relation, that as leucocytosis goes on, the white blood corpuscles diminish rapidly, at first, gradually increase, as has already been shown in the chapter dealing with blood.

These migrated cells may be met with in various situations:—(1) in the submucous eaves, where they are very abundant, usually placed in rows or groups, often in the immediate neighbourhood of blood vessels; (2) in the mucoid connective tissue beneath the closed ends of the cardiac glands, where they are numerous and scattered singly (e. fig. 13 Pl. VIII). [Although the tissue between the glands is adenoid in character as in other mammals, that around and between their closed ends and the muscular mucosa is mucoid, consisting of a homogenous matrix in which are embedded fibres and cells. This arrangement is seen all along the alimentary canal of the hedgehog, wherein it differs from that of other warm blooded animals.] (fig. 13 Pl. VIII & g. fig. 18. Pl. XIII)
(3) in the adenoid tissue between the glands, some reaching up to the lower ends of the epithelial cells lining the surface of the organ; (4) in a few other localities where they occur in small numbers, as in the lymph follicular tissue of palatine glands, etc.

What function this migration may subserve, how long it lasts, or when the cells begin to disappear, I am at present quite unable to state; their vast numbers would indicate that they are of some importance in the economy of hibernating animals.

Another remarkable point is the almost total absence of plasma cells in the alimentary canal below the esophagus, for we have seen they are only few in number in summer and appear totally absent in winter, and this is all the more striking when compared with their frequency in the tongue and connective tissue of the body generally; if they are over fed cells which they seem to
be, we would expect to find them in far greater numbers in these localities, where the food is absorbed, than elsewhere in the body, whereas they are almost absent here, though numerous enough in the connective tissue of the mesentery.

The stomach offers no other remarkable changes consequent upon the hibernating condition.
The Small Intestine.

The intestine of the hedgehog is a thin narrow tube about five feet in length, which though of some thickness near the pylorus, that is in the part of it which contains Brunner's glands, quickly narrows down into a tube of uniform caliber to near the cecum where it again widens out a little. Except in the duodenum the thickness of its wall never exceeds 2 millimeters. It has four coats, which from within outwards are: a mucous membrane, about 1.1 millimeter in thickness; a submucous, which is thin and measures 0.1 to 0.2 millimeter; a muscular, the thickness of which varies from 0.25 to 0.40 millimeter; and a peritoneal or perims of extreme tenuity.

The Mucous Membrane.

When the intestine is looked at from within, it presents a uniform granular appearance, there being no valvulae conniventes in it, even in
sections the mucous membrane is seen to be hardly convoluted at all, but presents numerous leaf-like projections above its surface, the villi, and tubular depressions, the glands of Lieberkühn, which are very much more numerous than the villi, two or three glands being found in the interval between two villi. The membrane is limited externally by a muscular layer which is usually in only one layer.

The villi.

The villi are leaf-like (Klein '47) having a broad flattened body supported on a long narrow stalk. The length of the villus varies in different specimens from 1.0 to 1.8 millimeter, the average being about 1.5 millimeter; the breadth in the widest part of the body about 0.1 millimeter. They are covered on their free surface by a single layer of columnar epithelial cells, (Fig. 16 & 17. Pl. XI) situated on a basement membrane, probably composed of somewhat flattened nucleated connective tissue cells.
which are of the same nature as the cells of the adenoid reticulum composing the body of the villus. In the centre and reaching almost to its free extremity is, as a rule, a single lacetal vessel, beside which a series of muscular fibres may be seen passing up the villus from the muscularis mucosae, accompanied by numerous capillary blood vessels.

The epithelium of the villus.

The columnar epithelium lining the free surface of the villus consists in a single row of columnar cells, placed side by side and united by a little cement substance; each cell is somewhat pyramidal in shape, the base of which is turned towards the lumen of the intestine, the apex directed towards the core of the villus, it possesses a protruded horn at its free end, and a conspicuous rounded or somewhat oval nucleus in its middle; though somewhat nearer the attached than the free end. The protoplasm is granular owing to a fine network, and the nucleus
exhibit a definite nuclear membrane and a nuclear network, in which there may be one or more nodal points, the nucleoli. (a, fig. 17 Pl. XI; and a, fig. 19 Pl. XII.)

Between the attached ends of these cells, one may often be observed, nuclei of other smaller cells similar in appearance to the columnar, but differing from them in shape and the absence of fine lines they have been called replacement cells by Forsh (46) (a, fig. 17 Pl. XI.) Wanderer cells may also be seen between the columnar cells; they vary in quantity and situation at different times.

Mingled with the columnar are numerous chalice cells which appear as clear transparent blebs filled with mucigen; in some preparations these cells exhibit a very long stalk in which is situated a wedge-shaped nucleus, which differs in its staining powers from the nuclei of the ordinary columnar cells, in as much as, in preparations stained with basic carmine, eosine, and haematoxylin, it keeps the red
lorry carmine stain, which is drawn from the nuclei of the other cells by the haematoxylin. (d. fig. 14 Pl. vii) The protoplasm which is reduced in quantity and concentrated round the nucleus has a granular appearance owing to its network; the remaining portion of the cell is clear, distended with mucin, and sometimes exhibits a very delicate large-meshed network at its periphery, which is some of the general cell network stretched by the contained substance. The cell is open at its free end and often presents a plump of transparent material projecting from it, which differs from that in the body of the cell in staining of a very deep blue with acid haematoxylin; it is no longer mucin having been converted into mucin. (g fig. 11 pl. vii)

The Reticulum of the Villus.

The body of the villus is filled with a delicate adenoid reticulum which is attached on the one hand to the central lacteal and on the other to
a kind of membrane composed of similar cells to those of the reticulum which have been flattened out to form a perforated basement membrane for the epithelial cells to rest upon, and which sends its prolongations of between them, to be lost in the cement substance between the cells. [Watney, Klein 47 etc.]

The reticulum is composed of a network of branched connective tissue corpuscles anastomosing by their processes, now and again at nodal points a nucleus may be seen, but this is by no means always the case; foster 46 looks upon this as an imperfectly formed connective tissue of the usual type. The meshes of this tissue contain very many lymph corpuscles, the rounded deeply stained nuclei of which render them conspicuous, also here and there a white blood corpuscle may be seen, readily recognized by the three or four nuclei which it contains and also by the protoplasm
Staining yellow with benzopurpurin B. A few larger endothelial cells may sometimes be seen with oval nuclei and a cell plate which stains pinkish with eosin and yellow with benzopurpurin; they are probably somewhat flattened connective tissue corpuscles and may have become detached from the reticular lamina.

Blood Vessels of Villus.

Immediately under the basement membrane there is a rich plexus of capillary blood vessels, often of large caliber, ramifying and anastomosing; the nuclei of the endothelial cells composing their walls may be seen at intervals; they are recognized by their large size and elongated oval shape. These capillaries spring from an arteriole which arises in the submucous coat, pierces the muscularis mucosae, and may be traced for some distance of the stalk of the villus. (a fig. 18 Pl. XII).

Muscles of Villus.
Many thin strands of non-striped muscular fibres may be seen in the stalk of the villus; they proceed from the muscularis mucosae pass upwards and spread out in the body to become attached to the adenoid reticulum, at the extremity and sides of the villus; the strands are often of extreme thinness exhibiting not more than two or three muscle cells abreast. Occasionally some of these muscle fibres are seen to run obliquely at the end of the villus.

**Lacteal.**

The lacteal is a wide lymphatic vessel situated in the centre of the villus; it reaches up close to the basement membrane at the free end of the villus, where it expands into a rounded extremity which appears closed; it is lined by endothelial cells the nuclei of which are often visible. If the tube be traced outwards it is seen to become extremely thin at the neck and to remain of this small pipe, until, after a slightly
precious course, it pierces obliquely the muscularis mucosae and opens into a wide lymphatic vessel in the submucous coat. (la & l, fig. 18 Pl. XII.)

There appear to be no valves to prevent regurgitation taking place in this tube; but its obliquity, its tenacity and the planting direction it takes in passing through the muscularis mucosae, are no doubt sufficient to prevent any backward flow, especially as contraction of the muscularis mucosae as a whole would tend to close the tube at the same time as it shortens the villus; for as Foster points out, when the muscular fibres contract they shorten the villus, in thus becoming shorter the body of the villus becomes proportionally broader; price probably no great change of bulk in the reticulum takes place, in this broadening the part to give way will be the loc-keal vessel, which, thus made broader and longer, becomes filled with chyle; when the muscular fibres relax, the
reticulum, the bars of which have been put on the stretch in a lateral direction, by elastic reaction brings back the villus to its former length and the lacteal channel elongates becomes narrower and has its contents expelled. If this be true then we can readily imagine how such an arrangement as that figured on Plate XII would act. Every time the muscles contracted the tube would be contracted below and dilated above, and at each relaxation of the muscles the opening below being patent would allow of the passage of the chyle into the lymphatic situated in the submucosa.

Lieberkühn's follicles.

0.3 to 0.6 millimeter in length, are simple tubular glands, lined by a simple layer of columnar epithelial cells situated on a basement membrane, which is very conspicuous especially at the closed ends of the follicle, where spindle shaped nuclei may be seen in it, (b. fig. 18 Pl. XII)
it may possibly be a true Delbecq's membrane in this position. The closed end of the follicle has a wide lumen which narrows to quite a small channel before opening on to the free surface of the intestine. The epithelial cells of these follicles differ somewhat from those covering the villi. They are shorter, narrower, cleaner in appearance, and possess a much more oval nucleus, which is situated quite near their attached ends; the hem through present is very thin and the fine protoplasmic network of the cell more open (b. fig. 17 Pl. XI).

During the active condition both parts of cells stain yellow with benz per
ferroine B. (a. fig. 16 Pl. XI) but during the resting condition, the difference is very conspicuous between them. The cells of Lieberkühn's crypts hardly at all even tincting with yellow (b. fig. 17 Pl. XI) whilst some of the villus stain deeply with the same colour. (a. fig. 17 Pl. XI)

Scattered among these are some chalic
cells identical with those over the villi.

The cells covering the surface of the intestine between the open ends of Lieberkühn's glands resemble those covering the body of the villus, whilst those covering the stalk of the latter resemble those of Lieberkühn's crypts, and a transition which is somewhat gradual may be seen between them.

(Fig. 16 p. XI)

The tissue between the crypts of Lieberkühn is adenoid and presents the same characters as that in the villi, it contains a few blood vessels. The closed ends of the follicles are separated from the muscularis mucosae by some considerable amount of tissue, which is not adenoid but muscular in character, similar to that of the stomach already alluded to; it consists of a gelatinous matrix containing fibers and cells, the spindle-shaped nuclei of which might cause it to be mistaken for non-striated muscle, but it is readily distinguished by its reaction to various
...dyes, as for example, picric-carmine in which it always stains pink like connective tissue, and not brownish like plain muscle. (q. fig. 18 Pl. X.) This tissue forms up some little distance between the closed ends of the follicles and into the stalks of the villi, where it soon merges into an adenoid network.

**Muscularis Mucosae.**

A single layer, the cells of which run longitudinally; very thin fibres pass from it into the villi as already described, and also up between the intestinal glands forming muscular rings round their mouths, they are attached to the adenoid reticulum.

**Sub-Mucous Coat.**

0.3 to 0.1 millimeter in thickness, except in duodenum, where it is very thick, and will be afterwards alluded to.

The coat is composed of a dense connective tissue, the fibres of which have a tendency to be disposed vertically, many of them pierce the muscularis mucosae along.
with the lacteal and blood vessels and
pass up towards the villi. Many connec-
tive tissue cells may be seen in it, also
some lymph corpuscles, they resemble in
every respect those described in the
submucous tissue of the stomach.
Large blood and lymphatic vessels are
situated in this coat, as well as the
ganglionic plexus of Meissner (S, fig. 8
Pl. xii) Peyer's patches and other soli-
tary glands are found in it, in their
usual situations.

Muscular Coat.

0.15 to 0.4 millimeters, with an average
of 0.3 mm in thickness, consists of
two layers of non striped muscle. An
inner, the cells of which are circularly
arranged, has an average thickness of
0.2 millimeters, and is the thicker
layer of the two, and often exhibits
near the submucous coat a peri-
detached, denser, band, a few cells
thick, separated from the general bulk
of the layer, by a little loose con-
nective tissue.
The outer coat, the fibres of which run in a longitudinal direction, measures only 0.1 millimetre in average thickness, and is separated from the inner coat by a little loose connective tissue containing the ganglion cells of Auerbach's plexus and some blood vessels.

The peritoneal coat consists of an extremely thin layer of connective tissue lined by a single layer of endothelial cells.

**Changes in the small intestine during hibernation.**

The most conspicuous change is seen in the cells lining Lieberkühn's glands, which during hibernation are very clear, and stain hardly at all with hematoxylin, whereas those of the villi stain deeply, appear much more granular.

The number of chloride cells seems to be greater, possibly owing to more cells being filled with mucigen, for during winter their activity like that of the body generally will have
decreased, the cells will discharge their contents less frequently, and hence the clear cell will appear more numerous, though in reality there probably are about the same number of chalice cells all through the year. This slowness of action of the mucous forming cells is also demonstrated by the absence of mucin from the lumen of the tubule's glands, and from the general surface of the villi, though Valentin has said that the small intestine is lined by a skin of mucin during hibernation, I have failed to find it.

During summer if a villus be looked at from above, the epithelium on pursuing down appears full of little rod-shaped nuclei, which I thought might be those of wandering cells, but on looking at specimens stained as above described in broman-carmine, eosine and haematophili, these rod-shaped bodies remain of a red color, just as we have already seen that the nuclei of chalice cells do, and
I believe that they are the nuclei of Charlcii cells, though it seems difficult to believe that Charlcii cells can be numerous, as the number of melii would necessitate. These nuclei are perhaps best seen during hibernation, as the number of lymph corpuscles is greatly diminished in the core of the villus. White blood corpuscles or wandering cells appear to have become more numerous both in the mucous and submucous coats where they are often aggregated into little clusters, and show signs of division. Plasma cells seem entirely absent.

No other change worth recording occurs, the tissues however offer the same difficulty in staining already referred to.
The Duodenum.

This part of the intestine is of no very great extent in the hedgehog, its submucous coat is devoid of Brunner's glands throughout its greater portion, they being confined to the immediate neighbourhood of the stomach. In longitudinal section these acini appear in a wedge shaped mass, 8 millimeters in length, with its base at the pylorus, and its apex directed towards the small intestine. Brunner's glands are therefore arranged in the form of a truncated cone ensheathing the mucous membrane of the duodenum, and greatly increasing the thickness of its walls.

The Mucous Membrane.

The mucous membrane of the duodenum is directly continuous with that of the pyloric portion of the stomach, it is similar in structure to that of the small intestine generally but the villi and follicles of
Lieberkühn (0.4 mm in length) are shorter and the former less numerous.

It is pierced by the duct of Brunner's glands which are very numerous. (d. fig. 15-Pl.x)

The transition between the mucous membranes of the stomach and that of the duodenum is permentant abrupt. (i.e. fig. 15-Pl.x); the muscularis mucosa, (m. m. fig. 15-Pl.x) which is in a single layer, is continuous with that of the latter organ, and fibres pass up from it into the villi, between the intestinal glands, and penetrate also into the sub-mucous coat to pass between the acini of Brunner's glands (u. fig. 15-Pl.x); the tissue between it and the closed ends of Lieberkühn's follicles is small in amount and adhered in character, differing therefore from the tissue found in similar localities in the stomach and intestines generally, and which does not begin to make its appearance in the duodenum till some distance beyond the last of Brunner's glands.
Sub-mucous Coat. (see fig. 15, Pl. X)

The sub-mucous coat of the duodenum is very thick near the stomach (3.7 mm) from which it is separated except just under the muscularis mucosae by the pyloric sphincter; it gradually becomes thinner as we recede from that organ, being only 0.9 mm. in thickness at the narrow end of Brunner's glands, and gradually passing into that of the small intestine becomes of the same price as in the intestine generally i.e. 0.3 mm. in vertical extension. Near the stomach it is filled with the compound tubular glands of Brunner, the lobes of which are separated from each other only by a little ordinary connective tissue and some muscle fibres.

Brunner's Glands. (see fig. 15, Pl. X)

They are compound tubular glands divided into lobes and lobules, from which numerous ducts pass upwards piercing the muscularis mucosae to open on the surface of the duodenum.
between Lieberkühn's follicles (d. fig. 154-6).

The gland acini are lined by a single layer of columnar, clear, epithelial cells presenting an oval nucleus deeply placed, which in hardened preparations often has an irregular shape; the cell network is fine and delicate, and plasm yellow with bengoaipurpurin B, giving a yellowish tinge to the cell otherwise stained of a faint blue colour with haematoxylin; the lumen of the tube is small, and outside the cells there is a basement membrane and a little plasm tissue. The ducts are lined by cubical cells, with a centrally placed oval nucleus, which become more and more columnar as we trace them towards the surface, but are never so tall as those lining Lieberkühn's follicles, and readily distinguishable from them by the position of the nucleus.

The cells of these glands very closely resemble those of the pyloric glands of the stomach, with which they are
according to foster directly continuous.
Below the lobules and situated in
the connective tissue of the sub-
mucous coat are a few ganglion cells
of Meissner's plexus some of which may
occasionally be found quite near
the muscularis mucosae.

Muscular Coat.

The muscular coat consists of two
layers of non-striped muscle; an inner,
0.2 m.m. to 0.4 m.m. in thickness, the
fibres of which are circularly disposed,
and directly continuous with those
of the pyloric sphincter. (p.s. fig.15 Pl.x)

This layer has a very irregular out-
line internally, as it sends prolon-
gations up between the lobes of Bou-
neux's glands, which are separated from
it only by the basement membrane,
causing it to vary in thickness con-
siderably at short intervals, and to as-
sume a wavy appearance on section.
(C.m. fig.15 Pl.x)

The outer layer is very thin (0.02 m.m.)
it's fibres longitudinal in direction and
directly continuous with that part of the outer muscle layer of the stomach that does not enter into the formation of the pyloric sphincter (c.f. figs. Pl. X), the two layers of muscle are only separated from one another by a little loose cellular tissue, containing cells of Auerbach's plexus.

At the junction of the muscular coat of the duodenum with that of the stomach a triangular space is left which extends quite round it, and contains an artery and a vein, embedded in a little loose connective tissue, and which have a circular course round the junction (c.f. fig. 15 Pl. X)

The peritoneal coat is continuous with those of the stomach and intestine, and calls for no special description.

Changes which occur in the Duodenum.

After what has been already paid of the intestine little need be paid of the duodenum except with regard to Brunner's glands. The cells lining their
acini are less problem in winter, and consequently the lumen of the gland appears bigger; the cells are very granular, stain of a faintish yellow colour with hematoxylin, and their nuclei which appear quite round, are not situated so near their attached ends as in summer. These changes are similar to those which may be observed in these glands after active secretion is over, that is to say in the resting condition; if the ducts nothing need be paid, as they appear to undergo no change.
The Large Intestine.

The passage of the small into the large intestine appears somewhat abrupt to the unaided eye, the latter to smooth mucosal surface suddenly presenting transverse folds which rapidly increase in size and number. They are the Valvulae conniventes of the colon, which is exceedingly larger caliber than the rest of the intestine; there is a complete absence of ileo-colic valve and cecum.

With the microscope the transition is however seen to be less sudden, the muscularis mucosae gradually becomes increased in thickness, elevations at first pearly increasing little by little in size, make their appearance, and by insensible stages pass into the Valvulae conniventes of the large intestine; they are at first covered by somewhat tall villi, between the attached ends of which are short Lieberkühn's follicles, these villi gradually shorten.
and at least disappear whilst the follicles elongate, and by insensible stages merge into those of the colon.

Whilst these changes are going on in the villi, the mucous connexine tissue between the closed ends of Lieberkühn's follicles and the muscularis mucosae is becoming less and less visible, till in the large intestine it is reduced to a minimum; the closed ends of the follicles reaching down to and almost touching the muscularis mucosae. Pancreatic cells also increase in number as the colon is approached.

**Mucus Membrane.**

The mucous membrane of the large intestine presents a smooth surface internally, which is indented by the openings of numerous glands of Lieberkühn, which extend from the superficial zone quite down to the muscularis mucosae. The general surface is lined by a single layer of tall columnar cells similar to and presenting the
same appearances as those covering the villi of the small intestine, among them are numerous chalice cells, which however are not mounted on quite such long stalks as those already described Lieberkühn's follicles.

These glands which are larger and larger than those of the small intestine are not at all closely packed at their free ends, but owing to their expanded inner ends are crowded together below; they are lined by columnar cells similar to those of Lieberkühn's follicles of the small intestine, but chalice cells are much more numerous.

All the epithelial cells are placed on a basement membrane which is doubtless composed of flattened plate-like cells of the advenoid reticulum, of which the connective tissue of the mucous membrane consists. The meshes of this reticulum are full of lymphoid corpuscles and wandering cells, and is in all respects
similar to that of the villi. Lymph capillaries and wandering cells may also be seen passing up between the thin ends of the epithelial cells, but must not be confounded with the replacement cells found in this region.

Only a vestige of fibrous tissue exists between the ends of the glands and the muscularis mucosae, which is composed of more than one layer, these being often visible, from it, strands pass up between the follicles to form rings around these months, as may be seen in transverse sections of the mucous membrane, and finally become attached to the adenoid reticulum.

Sub-mucous Coat.

Similar to that of the small intestine it contains blood vessels, lymphatics and ganglia of Messner's plexus. From the blood vessels arterioles pass upwards, pierce the muscularis mucosae and running between Lieberkühn's follicles form capillaryplexuses around them.
Muscular Coat.

Consists of two layers of non-striped muscle continuous with those of the small intestine; both layers are complete, the inner and thicker, is circular in arrangement, the outer and thinner, longitudinal. Between the two is a little loose connective tissue with blood vessels and ganglion cells of Auerbach's plexus.

The peritoneum is similar to that of the small intestine with which it is continuous.

The changes which occur in this organ during hibernation are similar to those described in the small intestine and call for no further comment.
The Liver.

The fibrous capsule of the liver of the hedgehog is very thin and the processes which pass inwards from it are only just visible with low magnifying powers; the fibrous tissue of Glisson's capsule being also in small amounts, the lobules are very indistinctly mapped out, as in the human liver.

The lobules themselves are of small size, and the liver cells are arranged in them in very conspicuous columns, which radiate out from the central vein in a straight and almost regular manner, to near the periphery of the lobule, where the cells are arranged in a network, which gives to the lobule the appearance of a many-rayed star.

The structure of the liver of this animal appears to belong to the tubular type, though it has been recently maintained by Shore and
Lewis Jones that the vertebrate liver is not built on this plan, but they did not examine that of the hedgehog. The tribules run an almost straight course, their central lumen is small though often distinct (c, fig. 21 Pl. 13) and is surrounded by the liver cells, which exhibit one or rarely two large, conspicuous nuclei, each with one or more nucleoli. The nuclei present a somewhat coarse network and have a distinct envelope. The cells are granular owing to their very fine and close meshed protoplasmic network; there is no basement membrane outside them, but each cell has a distinct envelope as may be seen in some sections, where the protoplasm has, in the process of hardening, become flattened from the cell wall (c, k fig. 21 Pl. XIII). Each tribule is surrounded by capillaries of the portal venous system (c, fig. 21 Pl. XIII).

The lumena, which are the bile capillaries, and in which no cuticular lining
can be seen, open at the mouths of the tubes into a narrow branched duct, (fig. 20 Pl. XIII) the intermediate, which, in this animal as in the guinea pig is, according to Klein, long and easily seen; it is lined by a single layer of flattened cubical, almost pyramidal, clear epithelial cells, the large oblong nuclei of which are placed transversely and render this portion of the bile duct a very conspicuous object, for the cells do not stain so pink with eosine and haematoxylin, as the liver cells, and by contrast, seem almost colourless. (fig. 20 Pl. XIII). Sections of these ducts may be seen scattered over the lobules in various positions in microscopic preparations of the liver. There is no basement membrane outside the ducts, though sometimes an elongated nucleus may be seen immediately under the epithelium, but this belongs to the walls of the capillary blood vessels which usually accompany the ducts, and not to an endothelial
basement membrane. (C, fig. 20 Pl. X11.)

The intermediate ducts open into larger ducts which are found at the margins and in the outer zones of the lobules; these ducts, the interlobular, are often well seen in the portal tracts passing from the larger ducts to the intermediate ducts; they are lined by a single layer of cubical or low columnar cells with oval nuclei placed vertically in the centre of the cells; they are placed directly upon a little fibrous tissue there being no intervening basement membrane.

The interlobular open into larger bile ducts, portions of which may be seen in the portal tracts. They are lined by well marked columnar cells with an oval nucleus in the centre of each, among which a chalice cell may now and again be seen. Between the tapering ends of the columnar cells, many small deeply stained nuclei may be seen.
surrounded by a little granular protoplasm, which belong to replacement cells; the lining epithelium of the larger ducts, therefore, be looked upon as stratified, though the columnar cells pass down between the smaller ones to be directly inserted upon the subjacent fibrous tissue, there being no intervening basement membrane. The wall of the duct is composed of ordinary fibrous tissue in which connective tissue corpuscles can be seen, with now and again a few circularly placed unstriped muscle fibres, which increase in numbers to form a distinct muscular coat for the larger ducts. Plasma cells are entirely absent from this connective tissue as from all other parts of the liver. Considerable quantities of small nervous glands may be seen surrounding, and opening into, some of the larger ducts; some are mere crypts in their walls, others possess distinct
acini lined by cells similar to those of the tongue and other regions of the body; these cells have short ducts lined by cubical cells, outside which is a basement membrane, by which they pour their secretion into the bile duct. Large numbers of lymph capillaries are found in the fibrous tissue of the bile ducts, producing loosely packed cords of lymph follicular tissue.

The blood vessels are conspicuous especially those of the hepatic venous system which are extremely large for the size of the animal, and the intra-lobular veins often partake of the nature of primum rather than that of ordinary veins, there being hardly any connective tissue outside their lining epithelium, and the capillaries of the lobules opening directly into them, otherwise the blood vessels do not differ essentially from those of other mammalian livers.
The liver cells are arranged in a row round the large vessels and under the capsule, the cells which enter into the formation of this row are inserted into the fibrous tissue by longer or shorter blunt processes, which give their sections a dentate or toothed appearance (t, fig. 22 Pl. xiv), each cell has one or sometimes two such processes projecting into the somewhat gelatinous connective tissue surrounding the veins (c, fig. 22 Pl. xiv) This arrangement is best seen in the case of the hepatic veins; the cells surrounding the portal veins and those under the capsule having less prolonged tooth-like processes: Except for these processes the cells do not differ in structure from the liver cells more deeply placed in the lobules (l, fig. 22 Pl. xiv). No doubt this arrangement gives a firm attachment for the vessel wall to the columns of liver cells. Lymphatic vessels are numerous in the capsule and in the fibrous tissue
of the portal tract.

Changes that occur in the liver during hibernation.

During hibernation, the cells of the liver present numerous golden yellow granules in the meshes of the extra-cellular network, which in unstained sections appear grouped into a broad fragmented band, running down the centre of a column of liver cells, the edges of the column presenting very few granules. (Fig. 23 Pl. x). This central grouping is easily accounted for, as on closer inspection each column of cells is seen to consist not of a row of cells placed side by side, but of a tube-like the central lumen of which is obscured by the close packing of the cells. As in that side of the cells turned towards the bile capillary, that the granules are found in the greatest numbers, ready, it would seem, to be passed into it by their active secretion.
Granules of this pigment are found scattered throughout the protoplasm of the cells, but are not numerous near the blood capillaries. (Figs. 23 & 24 Pl. XV and fig. 26 Pl. XVI)

The granules are insoluble in chronic salts, water, methylated spirit, absolute alcohol, ether, chloroform and balsam, do not blacken with philippid of ammonium or Barreto's reagent, and appear to give no spectrum with the micro-spectroscope; they therefore do not contain iron, though it is difficult not to associate them with blood pigment, or bile pigment, or with both.

A similar pigment is found in the blood capillaries scattered here and there in little masses.

Quincke says that the capillaries of the liver contain white blood corpuscles with iron holding granules of variable size in variable quantities, very numerous in old marmots. The liver cells show micro-chemically no iron reaction. He further states that there is a grea-
breaking down of red blood corpuscles, during hibernation, in the spleen, red marrow, and liver, and thinks that the iron is accumulated in these organs to be again used in forming blood pigment on the awaking of the animal. He used sulphide of ammonium as a test for iron in the livers and elsewhere, and obtained a blackening of the agow scales in the capillaries.

I repeated this and can confirm his observation.

But besides these masses there are large rounded or oval cells each with a purplish nucleus and which stain with ermin and haematoxylin of a golden yellow colour. (a, fig. 26 Pl. xvi.)

The nucleus is usually large, somewhat irregular, flattened and pushed to one end of the cell; the protoplasm is granular and appears to contain pale yellowish rounded bodies like those seen in the splenic cells; sometimes the cells seem full of bright golden yellow pigment granules of variable
some, brighter than those in the liver cells. These cells are found in the large veins coming to the liver and also in the lobular capillaries (as fig. 26 Pl. Xvi); they are not white blood corpuscles as they are uninucleated, and much larger as may be seen to the right of fig. 26 Pl. Xvi, where all the elements of the blood have been drawn side by side, to the same scale. I believe that these cells may come from the spleen, and that they are perhaps identical with the splenic cells; that they bring blood pigment to the liver which is after some alteration passed into the liver cells, as is that found loose in the capillaries, to be reconverted into bile pigment.

Whether this pigment is again used to form blood pigment as stated by Laimste (83) I do not know, but as the liver is not a blood forming organ, it is highly probable that pigment which has once passed its way thither would not again leave
it by the blood or any channel other than the bile capillaries, when it would be lost as blood forming pigment. During postnatal life we are well known the liver has a blood forming junction, but I have seen no evidence of such ascertainment occurring at the awakening of hibernating animals.

Certain it is that the liver of the pigment is abstracted, but what becomes of it cannot at present be said, possibly it is stored up in some form for future use.

On the whole it seems to me most probable that the pigment in the liver leaves it in the bile, whilst that of new blood corpuscles is formed in vivo.

Another change of minor importance may be seen in the liver during hibernation. Some cells seem to enlarge somewhat, their nuclei then increase in size, become distended and ultimately nearly fill the cell; (b. fig. 24 Pl. xiv)
after a time the over stretched mu
clear network ruptures, the nucleolus disappears or becomes adherent to the side of the nuclear envelope, the cell then appearing as a narrow band of very granular protoplasm surrounding a clear vacuole, which has a faint bluish tint in haematoxylin stained preparations. (c. fig. 24 Pl. xv) This vacuole still exhibits the nuclear envelope, as a deeply staining thick limiting membrane. Ultimately this also ruptures and the cell disappears.

Similar appearances may be seen in the liver during hibernation, but cells exhibiting such changes are far less numerous. This I believe to be the normal mode of death and removal of liver cells, but as all the processes of life are so much less intense during hibernation, the process is then slower and hence such cells are seen in greater number than in the active summer liver.

The cells of the liver are smaller, and more granular during hibernation.
than in summer, the bile and blood capillaries therefore become more visible during this period. When active the cells are swollen and obscure these vessels.
The Pancreas.

The pancreas of the hedgehog like that of the rabbit is thin and somewhat spread out, it is a compound tubular gland surrounded by a fine fibrous capsule which blends in perilia, dividing the tissue into lobes and lobules.

The ducts of the gland break up into branches for the lobes and these sub-divide again for the lobules; in the substance of the lobules the intra-lobular ducts are visible though small and not numerous, these again divide into intermediate ducts for the acini of the gland.

The large ducts are lined by a layer of tall, columnar cells, which in the largest ducts have very long oval, almost wedge-shaped nuclei that occupy nearly the whole cell. The tapering ends of the cells are very long and implanted in the pulmonary connective tissue, without the intervention of a basement membrane;
between these narrow tapering ends are placed one or more rows of small replacement cells, so that the epithelium may be said to be stratified. Outside the epithelium there is a considerable quantity of ordinary connective tissue arranged as a sheath, often containing considerable quantities of lymph corpuscles grouped together into little patches, also acini of mucous glands are occasionally found in the walls of the duct, which open into its lumen.

The lobular and lobular ducts are lined by a columnar epithelium composed of less elongated cells, the nuclei of which are oval, and do not occupy so much place in the cell, they appear to be planted on a basement membrane and have fewer replacement cells between their thin attached ends, they possess a sheath of fibrous tissue which is much thinner than that of the large ducts and devoid of mucous glands, though masses of
lymph corpuscles are present in it at intervals.

The intra-lobular ducts are lined by cubical cells with nearly spherical nuclei; they are situated in a basement membrane, and have scarcely any connective tissue round them; they divide and give rise to the inter-mediate ducts which are lined by flattened cells each with an oval nucleus placed horizontally in the cell; outside there is a basement membrane continuous with that of the intra-lobular duct on the one hand, and with that of a gland acinus on the other.

None of these epithelial cells exhibit the striated outer portion so visible in the intra-lobular ducts of the salivary glands, but present a beautiful, fine, open meshed, protoplasmic network.

The ducts are supplied by blood-venels that enter the gland at the hilus and break up into capillaries for the supply of the ducts and the
connective tissue which accompanies them, and ultimately break up into a rich capillary plexus for the supply of the gland acini, branches of which can be seen in the small quantity of connective tissue between them.

Numerous nerves also enter the pancreas along with the blood vessels, and appear to follow a similar course, nerve ganglia are developed in them at intervals in the neighbourhood of both interlobular and lobular ducts, they ultimately break up into fibrils to supply the secreting cells of the gland. A few ganglion cells may also be found in the fibrous capsule of the organ.

The acini of the gland are lined by a single layer of large columnar cells which vary in appearance with their physiological condition, they always exhibit two zones as described by Klein (47). Of these, the inner is granular, the granules are large
and according to this author due to small rods seen endwise, this part of the cell stains only very faintly with haematoxylin or borax-carmine (C, fig. 27 Pl. XVII); the outer zone is clear or very faintly longitudinally striped due to a peculiar arrangement of the delicate cell network; this zone stains more deeply than the inner zone with both haematoxylin and borax-carmine (C, fig. 27 Pl. XVII).

The relative size of the two zones varies with the condition of the gland; the larger the outer zone the more recently has the cell been in active secretion, when the gland has been inactive for some time the outer zone becomes relatively very small.

In the outer zone is situated the nucleus which is small relatively to the size of the cell, vesicular in character with a distinct membrane, a fine network and a single fractiform nucleus in about its
middle. (cf., fig. 27 Pl. XVII)

The cells are situated on a basement membrane, the elongated nuclei of which can be seen when the cells are not too distended from inactivity (cf., fig. 27 Pl. XVII); outside this there is a very fine and sparse connective tissue stroma (cf., fig. 27 Pl. XVII).

The lumen of the acini is small especially when the cells are distended, appearing as a mere cleft between neighbouring cells; when the gland has been active for some time the cells diminishing little in size, do not encroach so much upon the lumen, which may then be seen as an irregular tortuous channel between the cells. (cf., fig. 27 Pl. XVII)

There are no special "centro-acinal" cells blocks up the lumen.

The connective tissue of the gland is found in the capsule where it contains many fat cells; it is reflected in at the hilus round the large ducts and vessels which penetrate
into the gland at that spot; it is connective tissue of the ordinary type and contains all the forms of connective tissue corpuscles described when dealing with the stomach, with the exception of plasma cells which seem to be either entirely absent or very rare indeed. The lymph corpuscles are often accumulated in little groups.

In this gland during liberation as in the stomach the connective tissue becomes infiltrated with white blood corpuscles; but beyond this only such changes are observed as can be explained by a less active secretion.
The parotid of large size in the head is a compound tubular gland of a yellow colour. It is surrounded by a thin fibrous capsule which sends inward fine processes dividing the gland into lobes and lobules. This fibrous tissue is reflected into the lobes forming the ducts and blood vessels.

The main duct of the gland is divided into lobar branches for the lobes and lobular branches for the lobules, these latter divide into intra-lobular ducts situated within the lobules, and these terminate as fine ductules or intermediate ducts which open directly into the gland acini.

The lobar and lobular ducts are lined by a single layer of tall columnar cells with tapering attached ends, the present elongated nuclei in their centres and possess
beautiful fine protoplasmic networks. The tapering ends are placed imme-
mediately on the subjacent fibrous tissue which forms a thick outer coat for the duct; between their
thin ends are one or more layers of small replacement cells, which vary
in number with the size of the duct.

The lining cells of the lobular ducts are slightly less elongated than
those of the lobes and the fibrous coat is somewhat thinner.

The inter-lobular ducts which are very conspicuous objects owing
to their large size and peculiar staining properties are lined by
a single layer of columnar cells which present two distinct portions
an outer, which is nearly clear, with
only a very faint protoplasmic net-
work does not stain with eosine,
and an inner in which the network
is coarse and arranged in the form
of radially placed rods; this part
of the cell stains readily with co
pine and contains the spherical nucleus of the cell. They are situated on a basement membrane of flattened cells, with an micropinna
amount of connective tissue outside it.

The ductules are very narrow and lined with flattened cubical cells which make their appearance very rapidly, there being hardly any transition between them and the columnar rodded cells of the intra-
dobular ducts; they are not rodded but present a fine network with an oval horizontally placed nucleus in their centres, they rapidly become less and less cubical till near
the gland acini they become almost squamous; outside them there is a basement membrane continuous with that of the acini.

The gland acini which are larger than the ducts are lined by columnar epithelial cells which surround a very small tortuous lumen.
and exhibit a somewhat close, coarse network that gives them a very granular appearance; the nucleus which in spherical is placed near the attached end of the cell. The appearance of these cells varies somewhat with their plate of activity, outside them there is a basement membrane composed of flattened cells which rests immediately on a very small amount of peri-gelatinous stroma, containing connective tissue corpuscles. (s. fig. 28 Plxvii)

The blood vessels enter the gland at the hilus along with the nerves which are very abundant, but which possess no ganglia on their branches, they accompany the ducts in their ramifications, as do the blood vessels, and end like them in close connection with the secreting cells of the gland. Round the larger ducts and vessels there is some infiltration of the connective tissue with lymph corpuscles.
Sub-Maxillary Gland

This gland is similar to the parotid in structure, is large and of a yellow colour. It is chiefly a serous gland but contains some serous acini.

The ducts are similar to those of the parotid, in structure and arrangement, the ductules being more somewhat longer and therefore more conspicuous.

The penetrating acini differ in being lined by clear columnar cells with somewhat flattened nuclei pressed against the attached ends of the cells. The lumen is also more conspicuous. Outside the clear cells and between them and the basement membrane are the granular cells of the crescents of Grassi; they are very small however and not numerous.

The nerves that enter the gland exhibit ganglia on their branches.

It is impossible for me to state the differences, if any, that occur.
in the palivary glands during hibernation, because the animals from which they were taken were killed with chloroform; it caused such a copious flow of saliva that the glands were quite exhausted; some cells of the submaxillary glands presented an appearance similar to that produced by paralytic secretion.